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SOVIET INSTRUMENTATION AND
CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naia Tekhnika* in English Translation)

■ This translation of a Soviet journal on instrumentation is published as a service to American science and industry. It is sponsored by the Instrument Society of America under a grant in aid from the National Science Foundation with additional assistance from the National Bureau of Standards.

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■ This translation of the Soviet Journal *Izmeritelnaia Tekhnika* published and distributed at nominal subscription rates under a grant in aid to the Instrument Society of America from the National Science Foundation. This translated journal, and others in the Series (see back cover), will enable American scientists and engineers to be informed of work in the fields of instrumentation, measurement techniques and automatic control reported in the Soviet Union.

The original Russian articles are translated by competent technical personnel. The translations are on a cover-to-cover basis, permitting readers to appraise for themselves the scope, status and importance of the Soviet work.

Publication of *Izmeritelnaia Tekhnika* in English translation started under the present auspices in August 1959 with Russian issue No. 1 of January 1958. The six issues of the 1958 volume year will be published in English translation by December 1959.

All views expressed in the translated material are intended to be those of the original authors, and not those of the translators, nor the Instrument Society of America.

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Subscription Prices:

Per year (6 issues) starting with 1958, No. 1

General: United States and Canada	$20.00
Elsewhere	23.00
Libraries of non-profit academic institutions:	
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Single issues to everyone, each	$ 6.00

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Subscriptions should be addressed to:

Instrument Society of America
313 Sixth Avenue, Pittsburgh 22, Penna.

Translated and printed by Consultants Bureau, Inc.

Number 4 - July-August 1958

English Translation Published December 1959

Measurement Techniques

The Soviet Journal Izmeritel'naia Tekhnika in English Translation

Reported circulation of the Russian original 8,000.

Izmeritel'naia Tekhnika is an organ of the Academy of Sciences, USSR

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WIDER APPLICATION OF AUTOMATIC INSPECTION

The historic resolutions of the 20th CPSU Congress paid particular attention to the decisive factor in technical progress, the mechanization and automation of industry. The present stage of industrial development, including the engineering industry, is characterized by the transition from the mechanization and automation of separate processes to complete mechanization and automation of industry.

On May 12 to 15 an All-Union Conference was held in the Great Kremlin Palace in Moscow on the complete mechanization and automation of industry and the increased production of instruments and automation equipment.

The conference was attended by many representatives of industry, scientific research and development organizations, councils of national economy, Republic state planning committees, by scientists, technicians, innovators and inventors as well as by party, Soviet and trade union representatives.

Deputy Chairman of the USSR Council of Ministers and Chairman of the USSR State Planning Committee, I. I. Kuz'min and other speakers noted the role of complete mechanization and automation of industry as a powerful means for technical progress and increased labor productivity, described the experience gained in this connection and suggested concrete measures for their implementation.

It is common knowledge that production automation is closely connected with measurement techniques. In order to supervise and control industrial processes automatically either in an engineering automatic line, in the power, chemical, oil or any other industry, supervisory and measuring instruments are required as well as regulators which provide the desired accuracy in all the stages of industrial production.

The introduction of modern technique and automation of production raises the performance requirements of the measuring equipment, its expected accuracy, stability, reliability and the possibility of its systematic checking.

Our country possesses a large network of state inspection laboratories for measuring equipment which in conjunction with the industrial test laboratories transmit the correct and accurate values of state standards down to the workshop level, thus ensuring a uniformity of measurement throughout the territory of the USSR. The Institutes of the Committee for Standards, Measures and Measuring Instruments produce new (and improve old) state standards for various measurement units, widen the scope of measurement and improve its accuracy.

Although in the sphere of the metrological science and the production of standard instruments we have in recent years advanced considerably, we still lag in satisfying the demand of our industry in instruments and means of automation both with respect to quantity and especially the variety of types required.

The lag time between the design of new instruments and their mass production is still too long. In recent years many types of instruments were developed and their experimental models produced for measuring high and low pressure, height, density and thickness, as well as instruments based on radioactive isotopes and ultrasonics, which have various advantages over the older types since they can measure without introducing measuring elements into the measured object. Yet these very useful instruments are not being mass-produced on a wide scale.

Many instruments and automation devices required for production automation have not been developed and are not being produced by the instrument-making industry. These include instruments for measuring high vacuum, viscous fuels, and corrosive media; balanced instruments for measuring pressure and pressure differences; long-immersion thermocouples for measuring the temperature of liquid steel; instruments for measuring and

automatic control of hydrogen-ion concentrations (pH-meters) with an accuracy of 0.01 to 0.05 pH; concentration meters for measuring and controlling automatically concentrations of multicomponent solutions of salts acids, and alkali. Mass production of miniature recording and secondary control instruments has not been organized.

The activity of the numerous development departments and scientific-research institutes should be coordinated as soon as possible in order greatly to shorten the time lag between the production of an experimental model and mass production of an instrument.

One interesting example can be cited. Three organizations are concerned with the design of a new type balanced differential manometer, namely the "Niiteplopribor," the "KIP" factory in Khar'kov and the "Tizpribor" plant in Moscow. This work is not being coordinated by anyone; the "KIP" factory is ahead of others in designing a better model of a differential manometer with temperature and pressure compensation. If the efforts of these three organizations were coordinated, industry could have received in a much shorter time balanced differential manometers.

The instrument-making industry must pay special attention to the quality and reliability of measuring instruments.

Inspection of instrument-making plants by the Committee and its laboratories revealed several instances of low-quality instruments being produced. A considerable proportion of manometers made by the Tomsk plant in recent years get out of order after three months' operation, whereas they are supposed to last at least 3 to 5 years; rack-mounted instruments made by the "ZIP" plant are unsuited to work even in mildly corrosive media and deteriorate rapidly when used in chemical plants or electroplating shops.

One of the reasons for this state of affairs is the use of materials which are below the standard required for instruments and especially for sensitive elements and also the weakness of the development departments carrying out the work.

The quality of instruments, their stability and faultless operation depend to a great extent on the prime materials used in their manufacture, such as precision alloys, and highly pure alloys and metals.

It is idle to raise the question of a sharp increase in instrument production without solving the problem of specialized production of standardized and specified details and components widely used in instruments of varied applications. In the near future it will be essential to organize special shops and factories for the production of sensing elements for instruments measuring high and low pressure, of bellows, membranes, single and multispiral springs, casings, thermocouple elements and leads to them, small-module gear-wheels, magnets, etc.

Specialization of component and detail production is economically necessary because specialized plants will be able to organize mass production and apply the most modern techniques and completely mechanize and automatize production.

Standardization and specification of components and details of instruments, by first selecting out of the great existing variety a rational minimum of the best types for such purposes, and ensuring their interchangeability, will provide the required conditions for centralized mass production and automation, will lower the cost of production and of the manufacturing equipment and reduce the time lag between the development and putting into production of new types of instruments.

The experience of automation both at home and abroad has clearly shown that a successful solution of this problem is only possible on the basis of standardization of components and units from which the automation equipment must be built up. We have a set of standards providing for general and unit interchangeability, including standards for preferred numbers, normal diameters and lengths in engineering, for tolerances and fits embracing all types of connections used in modern engineering practice with dimensions ranging from 0.1 mm upwards; for threads, gear drives, key, spline and coupling connections and other components and details, whose implementation is facilitated by the standards set for workshop and checking gauges as well as for electrical sorting devices and instruments for checking products in the course of manufacture. We have some 250 operative standards covering some 1500 types of instruments. The basic parameters of the greater part of measuring instruments in general use have been standardized.

However, standardization of certain units for automation purposes is lagging behind; this must be remedied in the near future. In order to ensure interchangeability of transducers, amplifiers, converters, secondary instruments and actuating mechanisms it is necessary to unify and establish standards for input and output parameters and connecting elements of the equipment used in automation.

Work in the spheres of standardization and metrology has ensured complete interchangeability of products in various economic regions of our country. The production of machinery from separately manufactured parts is made possible by their interchangeability. In 1957 alone over 55 million measures and measuring instruments were checked against standards and reference instruments and certified for use in our national economy.

This work, however, is far from complete, further systematic inspection of measuring equipment and its periodic repairs and adjustment is required.

At present it is impossible to check all the measuring instruments on the spot, some of them have to be taken to other economic regions and even to Moscow or Leningrad. The Committee for Standards, Measures and Measuring Instruments has taken the necessary steps to ensure that all instruments will be tested within their economic regions as early as next year.

Proper inspection in the process of production is of great importance. We paid little attention to the productivity of inspection work, which led to an inadmissible increasing of the inspection personnel in factories.

Losses due to scrap are still high in industry. Considerable sums are spent on the many inspectors employed in the engineering industry to trace bad work. Despite this large inspection personnel the quality of engineering products is as yet below the required level, and this produces large and unaccountable losses.

Automation of inspection as well as that of production inevitably leads to a rise in the quality of the goods produced.

The most efficient methods of inspection automation are those which are organically related to production and can ensure prevention of scrap and remove the physical and technical reasons for its occurrence. Continuous inspection will raise the productivity of labor in the finishing operations by 10 to 15%, will reduce scrap to a minimum and in addition to the money thus saved, which will amount to millions of roubles, it will free tens of thousands of inspectors for employment in actual production.

Good automatic devices for controlling finishing processes have been developed in the USSR: Such instruments were developed by the Committee's Interchangeability Bureau for all the main types of grinding machines. These instruments are highly accurate and stable.

Automatic inspection of finished products is used in the USSR in the automatic piston plant, in automatic lines for making piston pins, roller bearing, rotor shafts, etc. The inspection and sorting automatic devices produced for the automatic lines are highly efficient and accurate. The bearing races are checked automatically at high speed for 16 to 18 parameters with an accuracy of 1 to 5μ.

The main obstacle for the introduction of continuous inspection is the lack of preparation of the machine-tool industry for mass production of machine-tools equipped with instruments for continuous inspection.

In the proposed list of state standardization for 1959-1965 a number of items refer to industrial and inspection automation.

For the purpose of further development of industrial automation and ensuring interchangeability of transducers, amplifiers, converters, secondary instruments and actuating mechanisms, it is planned to carry out scientific-research and development work on the unification of input and output parameters and dimensions of connecting devices of instruments, and also of their components and details, to work out unified types of instruments and to establish standard classifications, types, parameter series, connecting device dimensions, technical requirements and methods of testing of pneumatic and electronic combined and unified inspection and control systems; on pneumatic amplifiers for telemetering and pneumatic systems and instruments; on electropneumatic converters; on electronic-pneumatic converters; pneumatic actuators; air-operated positioners; on unified electric, pneumatic, hydraulic, extensometric, acoustic and pulse counting transducers for measuring external and internal dimensions in engineering, pressure differences, low pressures, consumption, head of water and level, temperature, load, force, and strain; on automatic timers for production control; on unified types of secondary pneumatic and electric instruments; on unified electronic amplifiers for thermal-power control instruments, unified types of electrical regulators and actuators of general industrial application; unified types of high- and low-pressure, consumption, head of water, level and temperature relays; on standardized units and elements of automatic and semiautomatic inspection and sorting devices for inspection and sorting of mechanical details.

For the purpose of making inspection automatic and for the wide application of continuous inspection in the production of engineering details, it is planned to carry out research and development of the required instruments (including those for details with discontinuous surfaces) and to establish a standard range, types, parameters, technical requirements and methods of testing the measuring equipment used in automatic grinding.

In order to ensure the design of production automation to a certain pattern using standardized inspection and control equipment it is planned to develop and standardize a number of typical inspection and control schemes for automatic production.

In order to introduce mass production of the most rational and economic computers and calculating machines, required in production automation, it is planned to carry out research and development work and to establish standard types, parameters and technical characteristics for electronic computers and calculating machines generally applicable in industry.

The proposed plan of metrological research for 1959-1965 envisages a number of investigations in the sphere of automatic methods of measurement and recording.

In the sphere of measurements of length the development of more efficient methods of linear measurements has been singled out as a special problem. This work aims not only at raising the productivity of inspection work, but also at producing high-speed indicating instruments and developing automatic methods of checking linear and angular dimensions in our engineering and instrument-making industries.

Automatic inspection of measures with scale calibrations will provide the checking of each division of such measures, which is very important since precision scales of great length are used for the initial setting of highly accurate programmed machine-tools. At present such scales are checked at several points only owing to the great labor-consuming nature of the work.

In the sphere of measurements of mass, the application of electronic principles and various electrical and pneumatic recording devices provides an automatic indication of readings and possibilities of remote control of the scales. The solution of these problems will help to overcome the low level of development of our gravimetric industry as compared with that attained abroad. In order to increase the productivity of mass inspections of weights, the plan includes the development of automatic methods of checking commercial weights.

In the sphere of automatic temperature measurements it is planned to investigate the errors of recording and regulating static and dynamic temperatures when automatic instruments are used; to develop the equipment and investigate methods required for automatic checking of resistance thermometers and thermocouples; to develop automatic control systems for checking thermal instruments based on cybernetic methods.

In the sphere of electrical measurements it is necessary to raise still further the efficiency of checking methods and testing equipment and to spread the use of automatic instruments. In this connection digital display instruments seem to offer great possibilities since they have an accuracy approaching that of automatically compensated instruments or bridges and at the same time operate at a high speed, thus considerably speeding up the checking procedure. In addition the digital display methods and computor methods in general can be adapted in future for the calculation and immediate recording of test results. In connection with the increased production of electricity meters, the speeding up of their testing is becoming a pressing problem. The development of automatic equipment for their testing is planned.

In the sphere of radio measurements it is planned to develop methods of automatic precision measurements at high and superhigh frequencies.

Important work in the sphere of inspection automation in the engineering industry is envisaged by the seven-year plan of the Interchangeability Bureau of the Committee of Standards, Measures and Measuring Instruments. The most important of its activities is the development of methods and equipment for checking details in the process of their manufacture on machine tools. An all-round development and application of continuous inspection is the most promising development in modern measurement technique in engineering. Continuous inspection methods prevent scrap whereas other inspection methods can only locate it. Further development of instruments and methods of continuous inspection in the operation of machine tools is foreseen.

The development of new methods and equipment for automatic inspection of finished details is planned.

The plan also provides for the development of the equipment and methods for temperature compensation

in automatic and continuous inspection; for the development and improvement of the basic elements of automatic equipment, the converting devices, with the object of producing measuring systems with excellent operational and technological properties; and for the automation of the inspection of threads and gears.

The important problems facing the workers in our industry, in the wide application of complete mechanization and automation of production and in increased output of instruments and automation equipment, also apply to workers in the measuring instrument industry, to both instrument-makers and metrologists.

In order to achieve technical progress and improved labor productivity the metrological workers must play a leading part in the fulfillment of the following tasks: to provide high-quality instruments and automation equipment for the automation of production; to introduce continuous inspection in the engineering industry on a wide scale; to achieve complete uniformity in measurements and interchangeability of instruments; to develop highly efficient methods of automatic checking and inspection.

ORGANIZATION OF WEIGHT-MEASURING EQUIPMENT REPAIRS IN TECHNICAL REPAIR CENTERS

S. I. Gauzner

Of the many millions of measuring devices used in the national economy of the USSR, a leading place with respect to their number and importance is occupied by the weight-measuring appliances. The importance of these appliances is especially pronounced in agriculture where the entire agricultural output is measured by them and the collective farmers are paid for the working days they have put in on the basis of these measurements.

The rations for the animals and birds are weighed out and the quality of production is also determined by weighing (the weight of animals, birds, eggs, grain, etc).

Tentative data on the number of weighing appliances used in agriculture are given in the table below.

TABLE

Weighing devices	Quantity (items)	Cost of repair (in roubles)	
		per item	altogether
For trucks	30000	1000	30000000
For freight	280000	100	28000000
For cattle	15000	400	6000000
Table scales	280000	40	11200000
Industrial scales	60000	80	4800000
Other scales	6000	300	1800000
Weights	7000000	2	14000000
Total	–	–	95800000

The entire enormous stock is overhauled, as a rule, once every two years and sometimes even more often by the local-industry weight appliances repair plants, at a very high cost.

If the cost of transportation of these items to the repair plants and back is added to the figure obtained in the table, the repair of scales and weights in agriculture will amount in 2 years to 100 million roubles. Moreover, the plants repair the scales badly and they begin to give wrong readings long before the end of the two year period. This leads to bad accounting and often causes difficulties when agricultural produce is delivered to the reception centers.

The high cost of repairs is explained by the fact that the local-industry plants are very small with high overhead expenses. The low quality of repairs is due to these plant lacking in space, mechanical equipment and a sufficient number of measuring (standard) instruments. These plants are badly supplied with tools, material and spare parts.

The greatest defect of these repair shops, however, is their lack in qualified personnel. Trade schools have no courses for gravimetric mechanics and there is not a single technical college with courses for technicians engaged in the production and repair of weight-measuring equipment.

The lack of literature on the repair of gravimetric equipment makes the training of personnel even more difficult.

The time is now ripe for a radical solution of the lasting and acute problem of the repair of weight-measuring equipment in agriculture with the object of reducing its cost and improving its quality.

The most rational solution of this problem seems to be the transfer of repairs of the weight-measuring equipment used in collective and state farms to the technical repair centers.

The placing of the repair organizations nearer to the collective and state farms where the equipment is used and the smaller overhead expenses of the technical repair centers as compared with the local-industry plants is certain to reduce the cost of repairs.

The technical repair centers will be able to carry out current repairs, which will increase the interval between overhauls of the measuring equipment and thus reduce still further the cost of its maintenance.

The total saving in the maintenance of the measuring equipment, if it is transferred to the technical repair centers, will be of the order of 15 to 20 million roubles per year.

Even if we assume that the saving will be smaller, the improved quality of repairs will be a good enough reason for transferring the repairs to the technical repair centers.

In order to be able to carry out this transfer, crews for the repair of weight-measuring equipment must be organized in the technical repair centers. No additional engineering equipment will be required by these crews, since the existing equipment of the technical repair centers is more than ample to satisfy their needs. It will only be necessary to supply the technical repair centers with standard measures and spare parts for the weight-measuring equipment and to send them specialists in repairing scales and weights.

When these crews are organized, special attention should be paid to supplying them with standard measures and spare parts. Industrial establishments of a number of councils of national economy could render the technical repair centers considerable assistance in this respect.

Thus, the Stavropol' gravimetric repair plant could supply the technical repair centers with scales and weights of the 3rd category; the P. Starostin (Odessa) plant could make 2nd category scales with a weight carrying capacity up to 1 ton and 3rd category 500 kg weights which are required for checking truck weighbridges; the L'vov automobile plant could make trucks of the type of ZIL-151 (as designed by the Committee's VNII) for transporting above weights; the Kokchetav and Armavir plants could supply spares for the truck weighbridges and freight scales; and the Moscow and Cheliabinsk gravimetric plants could supply spares for the table scales.

Two or three trade schools could specialize in training mechanics for the repair of weighing appliances preferably in Armavir or Kokchetav where there are large gravimetric plants making truck weighbridges and freight scales for agriculture.

For training gravimetric technicians special technical colleges should be set up in one of the above towns, or the gravimetric department of the Kaliazin engineering college reestablished (Kalinin region).

It is advisable to issue in good time text books dealing with the repair of gravimetric equipment.

Editorial note. The suggestions made in S. I. Gauzner's article naturally do not deal with all the questions connected with the organization of gravimetric equipment repairs in the Technical Repair Centers, which are questions of considerable importance to our national economy. For instance, he does not deal with the problem of selling scales to collective farms, a problem which has not as yet been solved satisfactorily. The Editorial Board requests readers to express on the pages of this journal their opinion of the questions raised by S. I. Gauzner.

INSPECTION OF MEASURING EQUIPMENT AND ENFORCEMENT OF STANDARDS AND TECHNICAL SPECIFICATIONS

V. E. Iakhontov

From the Experience of the Odessa State Inspection Laboratory for Measuring Equipment

From the fourth quarter of 1955 to the fourth quarter of 1957 the Odessa State Inspection Laboratory for Measuring Equipment inspected the condition and accuracy of measures and measuring instruments and the observance of standards and technical specifications in 37 leading industrial establishments of the Odessa region.

The basic industries of the Odessa region and the Odessa economic administrative district, whose boundaries coincide, consist of the food industry (about 60%), engineering (25%) and light industry (13%).

In order to exercise technically competent enforcement of GOST and technical specifications the supervisory-inspection group of the laboratory was enlarged, in view of the outlined distribution of industry, by the appointment of two engineers: a food industry expert and a mechanical engineer. It is contemplated to appoint a light-industry expert as well.

Failing special directives from the republic's administration, we select establishments for inspection in conjunction with the Council of National Economy or the Regional Soviet Executive Committee (depending on to which administration the establishment belongs) when information is received that production specifications are not being observed or that the products are of low quality.

5 to 6 days before the inspection the Chief of the laboratory selects an inspection crew and appoints its head, a specialist requainted with the industry to which the plant in question belongs.

The head of the inspection crew comes to the establishment with a letter from the Chief of the Laboratory notifying the plant administration of the inspection and requesting it to appoint responsible representatives with the right to sign interim inspection reports.

On the basis of the information received on the plan of the establishment with respect to the types and quantities of products and complaints lodged against it recently (in the last one or two years), the head of the crew determines the types of commodities to be inspected and studies the relevant documents (GOST technical specifications, drawings, and unified instructions), which control the quality of production.

All the members of the inspection crew study the literature describing the technique and methods of testing and analysis of the products subject to inspection.

Next we inform the customers of the establishment and the corresponding quality-control departments of the pending inspection and invite them to take part in the inspection. For instance when inspecting the Belgorod-Dnestrovsk fish canning factory in 1957, we invited representatives of the State Fish Inspection, and Food Quality Inspector of the Ministry of Trade of the UkSSR, the Odessa office of the "Glavmyasrybtorg," and the City Trading Department to take part in the inspection; and when inspecting the Odessa shoe factory No. 2 we invited representatives of the Odessa Sovnarkhoz Light-Industry Administration and the "Glavtorgobuv" to take part.

Before starting the actual inspection we, as a rule, inform the secretary of the CPSU district committee in whose district the plant is situated.

Only on completion of the preparatory work do we start the inspection.

In the first day of inspection the crew, as a rule, together with the Chief of the Laboratory acquaint themselves with the technique of production and with the organization of inspection of production and the quality of products by means of measuring instruments used for inspection. This gives an opportunity to the head of the crew to draft a plan of inspection in which the tasks of each member of the crew are specified.

If there is no inspection program worked out by the Committee for Standards, Measures and Measuring Instruments, the head of the crew completes one and the Laboratory Chief approves it.

The previously obtained information on complaints and the information obtained on the first day of inspection on scrap and production losses help to find the production processes where scrap is most common and to determine the most typical defects in the finished goods and analyze their causes.

In the first few days of inspection (and in food plants always on the first day) samples of articles ready for dispatch and passed by the Technical Inspection Department are taken for inspection and are subsequently tested for all their parameters laid down in the GOST or technical specifications, special attention being paid to qualitative requirements which the plants do not check or check only once in a while.

Tests, analyses or measurements of articles are carried out in the establishments by our own means or with the assistance of the factory laboratories. Average samples of food products are moreover always sent for analysis to the Odessa city medico-epidemiological laboratory. Average samples, as a rule, are taken from large quantities of products in keeping with the procedure laid down in the corresponding GOST. A number of samples sufficient to characterize the quality of production is taken for inspection.

Since 1957 side-by-side with inspection of the quality of production at the plant the laboratory has started inspecting the establishment's products in the hands of the trading network. Thus, when inspecting Bakery No. 4 in the fourth quarter of 1957 we found on sale 8 nonstandard weight consignments of bread, rolls and bagels (3055 kg) and one consignment of bread unsatisfactory in its physical and chemical properties (600 kg). In the Odessa trading network 20 nonstandard consignments of bread rolls and bagels which were produced by Bakery No. 4 were condemned (about 2000 kg).

In the course of inspection we make interim reports on separate shops and sections of plants regarding the results of tests and checks of production. The interim reports serve as a basis for compiling the main report which contained only the defects and infringements of regulations discovered during inspection. The total damage caused by these defects or infringements is established when everything can be accurately accounted for. For instance when inspecting the Ivanov nail and wire plant it was estimated that owing to the production of overweight goods the national economy was deprived of 50 million nails and 7 million wood screws; the overweight metal amounted to 100 tons.

The inspection of the measuring equipment in a plant begins with a thorough checking of all, but in the first place, the most important, measuring devices. Our inspection consists in checking the technical conditions of measures and measuring instruments, the correctness of their installation (mounting) and operation, and the existence of stamps and certificates that they have passed state tests.

Special attention is paid to the accuracy of instruments and their availability for production testing.

Equipment used for important technological operations and for checking raw materials and finished products is checked. Thus, in the "Avtogenmash" plant faulty scales for weighing out furnace charges were discovered, and it was established that this resulted in wrong mixtures for charges. After checking the physical and chemical properties of two pig-iron smeltings of a total weight of 3500 kg we condemned them since they did not satisfy the technical specifications. In the machine shop of the Kalinin engineering works faulty dial gauges, micrometers, slide gauges and plug gauges were found, which were used by the Technical Inspection Department. Of the 197 details checked by the Technical Inspection Department, we rejected 73 since they did not conform to drawings and technical specifications. In checking wood screws at the Ivanov plant it was found that, owing to a faulty setting of the automatic machine, screw threads were not taper-cut. Owing to the lack of a hardness gauge and angle gauge the hardness and angles of the tangential cutters were not checked; the cutters were soft and deviated from the normal setting by 10°; hence, the thread of the wood screws was unsatisfactory. Incorrect temperature measurements with thermocouples when heating, tempering and annealing needles in the same factory led to a faulty heat-treatment. Owing to the deviation of the hardness of needles from the standard 32.5% were condemned.

In the course of inspection we advise the plant management on the purchase of measuring instruments and determine the possibility of introducing new measuring techniques at the plant. Moreover, we check the organization and quality of the administrative inspection of instruments from the point of view of ensuring accuracy and correct use of instruments at the plant.

The inspection of industrial establishments is carried out not only by qualified engineers and metrologists but also by other laboratory personnel who check instruments, test, weigh, etc., thus, freeing the engineerings

for a deeper consideration of the state of production and inspection at the plant, for finding defects in the condition of the measuring equipment and methods of measurement and for determining whether the plant is adequately supplied with modern measuring equipment.

The inspection of establishments is concluded in the following manner. After the signing of the report we hold a conference with the engineers and technicians of the plant at which the result of inspection are discussed in detail, causes of defects are brought to light and measures for their elimination outlined. Leaders of the party organization of the plant are invariably invited to these conferences.

In the decisions adopted, time limits are fixed for the eliminations of the defects and infringements of regulations.

The plant management is advised on the introduction of modern, more advanced methods of measurement.

The inspection results are brought to the notice of superior organizations such as Regional Soviet Executive Committees (with respect to local-industry plants) and the Councils of National Economy (with respect to their establishments). If important infringements are found at the plant the Regional and District Committees of the Party on whose territory the plants are situated are also informed.

On the basis of inspection information the Odessa Council of National Economy established a commission for checking the quality of production at the plants against the corresponding GOSTs, technical specifications and unified instructions.

In a number of cases we published articles in the local press on the basis of information obtained during inspection; as the result of this action, as a rule, measures were adopted for eliminating the defects.

INTERNATIONAL CONFERENCE ON MEASUREMENT TECHNIQUES

An International Conference on Measurement Techniques, prepared by the Hungarian Scientific and Technical Society on behalf of the International Preparatory Committee of the scientific and technical societies of Hungary, Poland and the USSR, will be held in Budapest from November 24 to 30, 1958.

The object of the conference is to exchange information on technical, organizational and economic achievement in the sphere of measurement techniques and instrument – making as well as to strengthen friendly ties between the scientists and specialists of the participating countries.

At the plenary sessions questions of general interest will be discussed; at sectional meetings, special questions, and at information sectional meetings, questions which have not been sufficiently discussed at the sectional meetings.

During the conference, an exhibition of Hungary's most up-to-date instruments will be held in the House of Technology. People attending the conference will have an opportunity to become acquanted with the work of Hungary's Scientific Organizations.

All questions in connection with Conference should be addressed to International Conference on Measurement Techniques, Budapest 5, Box 3.

LINEAR MEASUREMENTS

MEASUREMENT OF LARGE DIMENSIONS

F. P. Volosevich

(From the Experience of the Kirov Plant (Leningrad)

The existing devices for the measurement of large dimensions (over 500 mm) fail to satisfy all the requirements of industry. For this reason a number of plants are developing for their own use equipment for measuring large dimensions.

The Leningrad Kirov plant has developed and put into use the measuring devices described below.

Lightweight external dial micrometers with widened anvils. The micrometers made by the "Kalibr" works for measuring large dimensions are hardly suitable for their purpose because of their heavy frame (the frame of a micrometer with a range of up to 1 m weighs 14 kg). In addition, the frame is not reinforced by ribs and tends to bend, which cannot always be prevented by suitable modifications (for example, it is not possible to eliminate the misalignment of the axes of the screw and anvil in the plane parallel to that of the frame). It is very difficult to make precision measurements with such micrometers and most of these instruments must therefore be rejected. The "Kalibr" works should discontinue the manufacture of these micrometers.

We are now widely using welded lightweight dial micrometers with an extended anvil (Fig. 1). The weight of the lightweight instrument with a range of up to 1 m is only 5 kg instead of 14 kg; the micrometer has a dial and its anvil is adjustable, so that a micrometer of this type can be used for ± 100 mm outside its main range; in addition, the anvil is widened to 30-50 mm. It has a lapped face (with a groove) and is dead perpendicular to the center line of the micrometer which ensures a correct positioning of the frame with respect to the work being measured. All these improvements make the measuring simpler and ensure greater precision.

When the dial micrometers are used for measuring internal dimensions the dial is placed inside the frame and the anvil is turned with its spherical face outside.

For the adjustment of the micrometer to the required dimension, it is possible to use special adjustment gages which also have on one side a lapped, widened anvil with a groove, or gage blocks, or, finally, ordinary setting gages with a 5-10 mm gage block placed onto the widened anvil of the dial micrometer.

For everyday adjustment and inspection of large micrometers the workshop has two sets of special adjustable setting gages (Fig. 2). During the overhaul of worn spherical tips there is no need to expand the shortened instrument by hammering since a mere regulation of the tips restores them to the nominal dimension. One of the available sets is in use for one month, during which time the second set is being checked or, if necessary, repaired.

Minimeter with an extended column. When no measuring machines are available, and especially when the inspection division is small or when the measurements are made directly in the templet production section, it is possible to use a measuring head mounted in an arm moving on a straight column (Fig. 3). A minimeter or the optimeter tube can be used as a measuring head. The column can be 1-3 m long. The position of all parts, and, in particular, of the lifting table, is similar to that of an ordinary minimeter or a vertical optical comparator. The measurements are taken in a vertical position.

The minimeter is also used for checking micrometer and internal dial gages. In order to render the setting of the minimeter easier, 5 mm diameter holes are drilled at 100 mm intervals on a straight line along the entire

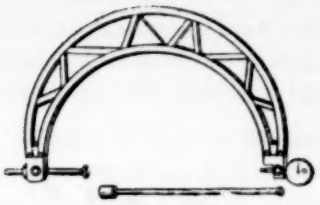

Fig. 1.

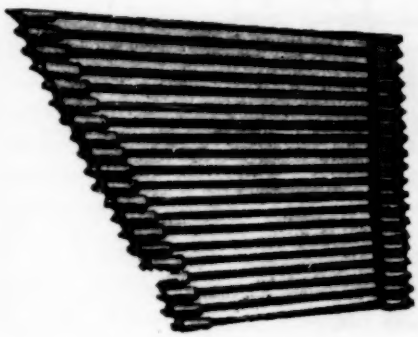

Fig. 2.

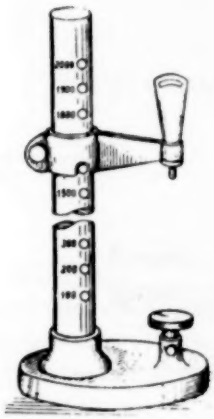

Fig. 3.

Fig. 4.

length of the column, and marked by relevant figures. The holes are datum points for setting and also fix the direction of movement of the arm along the vertical, for which purpose the arm has a special semicircularhole. The minimeter with a 25 mm long micrometer feed is set by means of gage blocks.

Gage block with foot. For setting the minimeter with an extended column and also during measuring on the marking table, and in particular when the dimensions of a component are large, we use gage blocks.

In addition to the standard sizes the Russian industry produces gage-block sets with dimensions of 100-1000 mm. These blocks have special holes to facilitate their clamping into special holders. Because of the smallness of the supporting area (9 × 35 mm), gages built up by wringing are very unstable when used in the vertical position.

For using gage blocks in this position on the marking table or on the table of a minimeter a special end block with a foot can be used (Fig. 4). The large area of the supporting surface of this gage gives stability when used on the marking table or on the table of a minimeter in a vertical position. The length of the gage measured from its base to the top plane is 50 mm and it should fully satisfy the requirements prescribed for gage blocks by OST 85,000-39 specification. The described gage block also has a hole which makes possible its connection to a bar of gage blocks joined by an ordinary holder and its use in a vertical position. For less accurate measurements a special screw-threaded foot can be used, to which the extension and the head of an internal micrometer head (Fig. 5) can be screwed.

Horizontal optical comparator for 3.5 m range. There was a need in the department for measuring large dimensions (up to 3.5 m), but no measuring machine of this size was available, and there was little point in sending instruments to the Central Measurement Laboratory for checking since too much time was lost in reaching the required temperature, especially in winter time.

This led to the construction of a horizontal optical comparator for measuring work up to 3.5 m in length. A 3 m long machine bed was used as the base. The universal table, the optical-comparator head, and the spindle with cantilever-type supports for internal measurements were taken from a horizontal optical comparator. The purpose and interaction of all the parts can be seen from Fig. 6, which also shows the 3 m long bed 1, the left-hand and the right-hand headstocks 2 which move on the machine bed and are locked by screws 3, rolls 4 fitted in both headstocks, the arms 5 of horizontal optical comparator, the comparator tail spindle 6, the comparator head 7, frames 8 for internal measurements and the work table 9.

The measurement procedure on this optical comparator is the same as on horizontal instrument and it is set by means of a master bar composed of gage blocks.

Device for measuring by means of gage blocks (Fig. 7). The 25 mm frame 3 with a permanent side member 4 can be moved on the base 1 by means of the micrometer screw 2. The position of the frame is indicated by the micrometer 5 which is also mounted on the base 1.

Fig. 5.

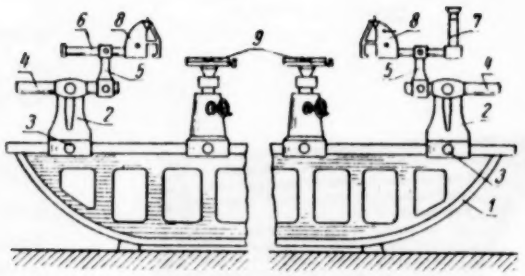

Fig. 6.

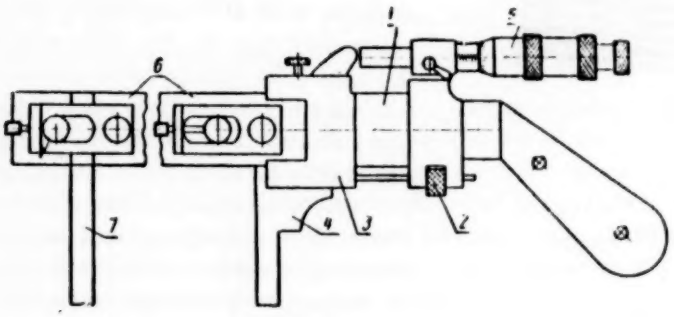

Fig. 7.

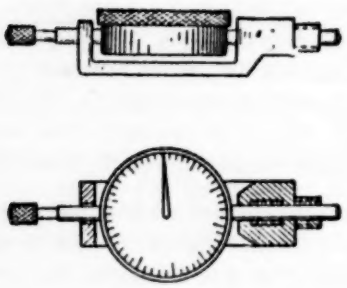

Fig. 8.

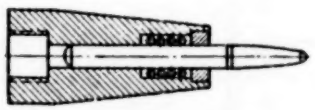

Fig. 9.

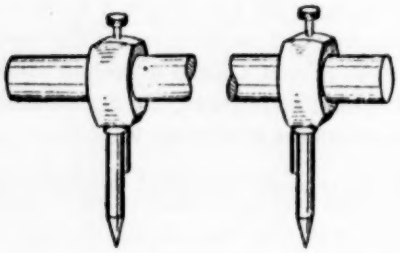

Fig. 10.

The end face of the base 1 is dead parallel to the working surface of the side member 4 and has a mirror-finished lapped surface. When the planes of the base and the side member coincide the micrometer indication is zero. A bar of gage blocks 6 of the required length is fixed to the end face of the base. The second side member 7 is wrung to the opposite end of the bar. The gage blocks are attached to the side members by means of holders normally used with 100 mm and longer gage blocks.

This device can be used for measuring at the workplace external and internal dimensions with a deviation of 20-25 mm from the nominal length of each block bar, which renders the measurement process simpler and faster and eliminates the need for composing a block of exactly the required dimension.

Internal micrometer. The ChIZ (Cheliabinsk Instrument Factory) internal micrometer enjoys a well-deserved popularity and has a number of advantages over the earlier types of internal gages. This instrument has a reinforced body, measuring contacts and a micrometer head, a wider measurement range, is supplied with a setting gage, and includes a number of other improvements. Its shortcoming is low sensitivity.

In order to increase the sensitivity we have replaced one of the fixed contact members arranged at the ends of the instrument by a movable type connected with a dial gage. The dial gage is mounted, like the extension pieces, on a special bracket attached in the same way as an ordinary extension piece (Fig. 8).

The entire unit (the bracket with the dial gage and the contact member) has a definite length which is fixed by means of the setting gage; this makes possible its use as an ordinary extension piece without first checking the total dimension of the internal gage. The internal gage can be adjusted within the range of 25 mm by means of a micrometer head to an accuracy of 1 mm, while hundredths of the millimeter can be read from the scale. The internal micrometer is also suitable for measuring narrow, stepped diameters and narrow grooves which are not accessible for an ordinary internal gage because its contact jaws have a relatively large diameter (8 mm) and a small length (3 mm), and touch the body of the instrument during the measurement. In order to overcome this shortcoming, measuring tips with thin spherical points which can be used in the same way as ordinary extension pieces can be screwed to the end of the internal micrometer (Fig. 9).

Scribing slide gage. For marking radii and for transferring dimensions of up to 4 m a hollow rod carrying sliding scribers with special flats (Fig. 10) is used in place of the ordinary heavy slide gage. Measuring methods have been developed at the plant which take into account the size, shape and accuracy of these instruments.

DETERMINATION OF THE MEASUREMENT ERROR OF LINEAR DIMENSIONS DUE TO MISALIGNMENT

G. S. Simkin

In measurements carried out on a comparator or a horizontal optical comparator a misalignment of the part being measured with respect to the line of measurement is always possible; in order to eliminate it the work table is usually turned and tilted until an extreme reading on the dial of the device is obtained. However, such a reading can only be found approximately and an error in the determination of the dimension being measured is always possible. The errors, due to misalignment can become especially large when, in measuring long lengths, such relatively inaccurate instruments as end-measuring rods, slide gages, etc., are used.

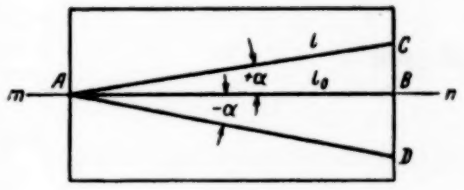

Fig. 1.

We consider in the following a law of the distribution of errors due to misalignment which is interesting in itself, and we also give some equations for the determination of the size of this error occurring in various length measurements.

Let us first consider the single-plane misalignment of the quantity being measured.

Figure 1 shows the probable position of measuring contacts during the measurement of the length l_0; α denotes the angle of misalignment. Taking into account the smallness of α it is easy to determine the error δ caused by the misalignment

$$\delta = AC - AB = \frac{l}{2}\alpha^2 = \alpha^2, \qquad (1)$$

if, for the sake of simplicity of calculations, it is assumed that $l/2 = 1$.

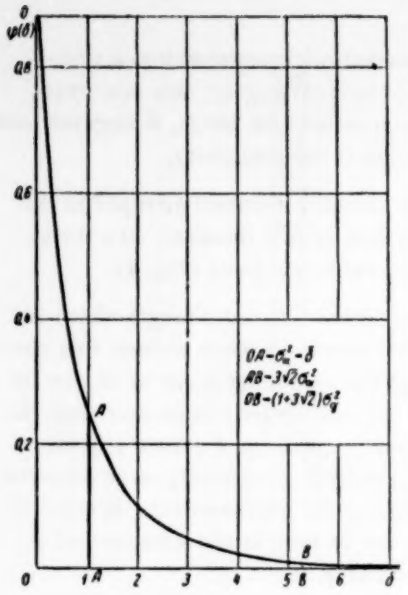

Fig. 2.

The assumption that δ is a random error is sufficiently well-founded. In fact, in repeated measurements it is unlikely that the misalignment remains the same; it is more correct to assume that the misalignment changes from measurement to measurement at random and that δ remains a positive value.

It is known [1] that for a positive δ the function of distribution of probability $Q(\delta)$ is determined from the relation

$$Q(\delta) = \begin{cases} F(\sqrt{\delta}) - F(-\sqrt{\delta}) & \text{for } \delta > 0 \\ 0 & \text{for } \delta < 0 \end{cases} \qquad (2)$$

Here $F(\pm\sqrt{\delta})$ is the function of distribution of probability of $\sqrt{\delta}$. In our case $F(\sqrt{\delta}) = F(\alpha)$ since $\sqrt{\delta} = \alpha$.

Let us assume that the density of the probability of α is $f(\alpha)$; then $f(\alpha) = F'(\alpha) = F'(\sqrt{\delta})$. Thus, the distribution of the density of probability of the random quantity $\varphi(\delta) = Q'(\delta)$ will be determined from the relation

$$\varphi(\delta) = \frac{1}{2\sqrt{\delta}}\left[f(\sqrt{\delta}) + f(-\sqrt{\delta}) \right]. \qquad (3)$$

In order to find $\varphi(\delta)$ in a real form it is necessary to know $f(\alpha)$. With regard to this function definite assumptions can be made: when the measurement of a length by means of the devices mentioned above are frequently repeated it can be expected that the remaining angle of misalignment α has positive as well as negative values. In addition, large misalignment angles will occur less frequently than small angles.

Thus, it can be expected that the type of the distribution curve of misalignment angles will be nearly symmetrical and it is possible to assume that the curve of normal distribution of α is also symmetrical. Taking into account that $\alpha = \sqrt{\delta}$ the Eq. (3) can be presented as

$$\varphi(\delta) = \frac{1}{\sqrt{2\pi}\sqrt{\delta}\,\sigma_\alpha} \cdot e^{-\frac{\delta}{2\sigma_\alpha^2}}, \qquad (4)$$

where σ_δ^2 is the scatter of the angle α.

It follows from the Eq. (4) that the error δ does not follow the normal distribution law; Fig. 2 shows the curve of its distribution.

Knowing the distribution of the density of the probability of the quantity δ it is possible to determine its mean value $\overline{\delta}$ and scatter σ_δ^2.

It is known that for a substantially positive value of δ its mean value is

$$\overline{\delta} = \int_0^\infty \delta\varphi(\delta)\, d\delta. \qquad (5)$$

By substituting into (5) the value $\varphi(\delta)$ taken from (4) we obtain, after making the necessary transformations:

$$\overline{\delta} = \frac{1}{\sqrt{2\pi}\,\sigma_\alpha} \int_0^\infty \delta^{1/2} e^{-\frac{\delta}{2\sigma_\alpha^2}}\, d\delta \qquad (6)$$

and after integration [2]

$$\overline{\delta} = \sigma_{\alpha}^2. \tag{7}$$

The scatter is

$$\sigma_{\delta}^2 = \int_0^{\infty} \delta^2 \cdot \varphi(\delta) d\delta - (\overline{\delta})^2. \tag{8}$$

After substituting into (8) the values $\varphi(\delta)$ and δ^2 and the integration, we obtain

$$\sigma_{\delta} = \sqrt{2}\,\sigma_{\alpha}^2. \tag{9}$$

For the assessment of the maximum error we assume its limiting value to be, according to the theory of measurement errors, $3\sigma_{\delta}$. Then, according to Eq. (9)

$$3\sigma_{\delta} = 3\sqrt{2}\sigma_{\alpha}^2. \tag{10}$$

Let us now consider the field of errors δ with respect to the real value of the dimension being measured.

In Fig. 2 OO indicates the position of the actual value of the dimension being measured, AA is the center of the zone of scatter of errors δ and BB is the limiting value of the error δ.

The distance between OO and AA is $\delta = \sigma_{\alpha}^2$. The field of scatter of random errors with respect to the center line of scatter is determined by the value σ_{α}^2 and $+ 3\sqrt{2}\sigma_{\alpha}^2$, while with respect to the real value of the dimension being measured this field is determined by the value $(1 + 3\sqrt{2})\,\sigma_{\alpha}^2$.

Thus, the maximum value of the measurement error with respect to the real value (we denote it by δ_{max}) is

$$\delta_{max} = (3\sqrt{2} + 1)\,\sigma_{\alpha}^2 = 5.2\,\sigma_{\alpha}^2. \tag{11}$$

We now find the probability of the occurrence of the error δ_0 is greater than δ_{max}.

It is known from [1] that this probability can be determined from the relation

$$p(\delta_0 > \delta_{max}) = 1 - \int_0^{\delta_{max}} \varphi(\delta)\, d\delta. \tag{12}$$

After substituting the values of $\varphi(\delta)$ from (4) and taking $\delta/2 = t$ we obtain

$$p(\delta_0 > \delta_{max}) = 1 - \frac{1}{\sqrt{\pi}\,\sigma_{\alpha}} \cdot \int_0^{\delta_{max}} t^{-1/2} e^{-\frac{t}{\sigma_{\alpha}}}\, dt \tag{13}$$

This integral belongs to integrals of the type [2]

$$\int_0^u t^{-1/2} e^{-kt} \cdot dt = \sqrt{\frac{\pi}{k}}\, \Phi\left(\sqrt{ku}\right). \tag{14}$$

Here,

$$\Phi(u) = \frac{2}{\sqrt{2\pi}} \int_0^u e^{-\frac{x^2}{2}}\, dx \tag{15}$$

is the integral of Laplace, the numerical values of which are found in tables given in books on the theory of probability and mathematical statistics.

The relation (14) can also be written in the form

$$p\left(\delta_0 > \delta_{max}\right) = 1 - \Phi\left(\sqrt{\frac{\delta_{max}}{\sigma_a^2}}\right) \tag{16}$$

After substituting the numerical values of δ_{max} we obtain

$$p\left(\delta_0 > \delta_{max}\right) = 1 - \Phi\left(\sqrt{3\sqrt{2}+1}\right) = 0.022 \tag{17}$$

Thus, the probability of the occurrence of an error exceeding the limiting value ($3\sigma_\delta$) is here 7 times greater than in the case of normal distribution $p(\delta_0 > 3\sigma_\delta) = 0.003$.

According to Eq. (11), and taking into account the quality $l/2$ which for the sake of simplicity was earlier assumed to be unity, the error δ_{max} is found from the relation

$$\delta_{max} = 5.2\frac{l}{2}\sigma_a^2 \simeq 2.5\, l\, \sigma_a^2. \tag{18}$$

If $\eta = CB$ (Fig. 1) denotes such value of the linear misalignment which is easy to determine, then the maximum angle of misalignment $\eta_{max} \approx \eta/1$. In this case it can be assumed that $\sigma_\alpha \approx \eta/3l$, then δ_{max} is

$$\delta_{max} \simeq 0.3\,\frac{\eta^2}{l}. \tag{19}$$

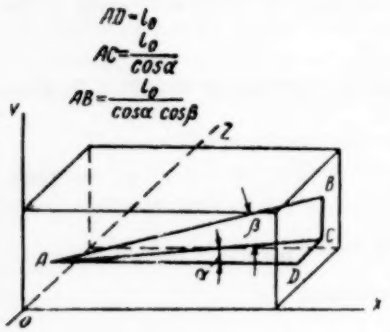

Fig. 3.

We considered above the problem concerning the misalignment of the dimension being measured occurring in one plane. However, in many cases, a misalignment in space takes place for example, during measurements on a horizontal optical comparator or on a comparator in which spherical or segmental contact members are used in internal measurements. Such misalignments can also occur in measuring the internal diameter of components by means of end-measuring rods. It should be noted that in measuring cylindrical parts by means of instruments with flat contacts the misalignment can occur only along the generating line of the cylinder, i.e., in this case when the Eq. (18) is correct.

Let us determine the size of the error for misalignments in space.

Here two cases are probable: 1) the distance being measured is defined by two parallel planes and 2) cylindrical parts are being measured.

1) Figure 3 shows the probable position of the measuring contacts during the measurement of the distance between two parallel planes.

Taking into account the smallness of misalignment angles α and β it follows from Fig. 3 that the measurement error due to misalignment in space is

$$\delta = AB - AD \simeq l_0\,[1 - \cos\alpha\,\cos\beta]. \tag{20}$$

On splitting $\cos\alpha$ and $\cos\beta$ into series, and using only terms not exceeding the second power we obtain

$$\delta \simeq l_0\left[1 - \left(1 - \frac{\alpha^2}{2}\right)\left(1 - \frac{\beta^2}{2}\right)\right],$$

or, after the necessary transformations,

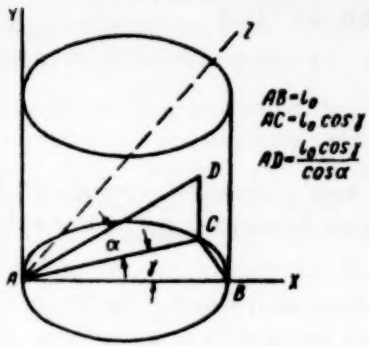

Fig. 4.

$$\delta \simeq \frac{l_0}{2}\alpha^2 + \frac{l_0}{2}\beta^2 = \delta_\alpha + \delta_\beta . \qquad (21)$$

Assuming that the angles α and β are mutually independent and obey the normal distribution law, we find that the errors α and β obey separately the law expressed by the Eq. (4) (see also Fig. 2).

Thus, the error δ is composed of two distributions $\delta_\alpha + \delta_\beta$. It can be shown [1] that the characteristic function for δ is

$$\varphi_\delta(t) = [\varphi_\alpha(t)]\,[\varphi_\beta(t)] = [(1-2i\sigma_\alpha^2 t)\,(1-2i\sigma_\beta^2 t)]^{-1/2} \qquad (22)$$

Calculations show that

$$\bar{\delta} = \sigma_\alpha^2 + \sigma_\beta^2; \qquad \sigma_\delta^2 = 2\left(\sigma_\alpha^4 + \sigma_\beta^4\right). \qquad (23)$$

Since there is no special reason to assume that the scatters σ_α^2 and σ_β^2 can differ a great deal, then it can be assumed with a reasonable accuracy that $\sigma_\alpha^2 = \sigma_\beta^2$. Then the last two equations can be written as follows:

$$\bar{\delta} = 2\sigma_\alpha^2; \qquad \sigma_\delta^2 = 4\sigma_\alpha^4; \qquad \sigma_\delta = 2\sigma_\alpha^2 . \qquad (24)$$

The maximum error δ_{max} with respect to the real value is

$$\delta_{max} = \frac{l_0}{2}\left[6\sigma_\alpha^2 + 2\sigma_\alpha^2\right] = 4\,l_0\sigma_\alpha^2 . \qquad (25)$$

And, finally, assuming as in the former case, that

$$\sigma_\alpha = \frac{\eta}{3l},$$

we obtain

$$\delta_{max} = \frac{4}{9}\,\frac{\eta^2}{l}. \qquad (26)$$

2) When internal or external diameters are measured by means of instruments with spherical contacts, the errors occurring as a result of the possible misalignment can be determined from Fig. 4 with similar assumptions and calculations.

$$\bar{\delta} = 0 \text{ and } \sigma_\delta = 2\sigma_\alpha^2. \qquad (27)$$

The limiting size of the error δ is

$$\delta_{max} = \frac{6l_0\sigma_\alpha^2}{2} = 3l_0\sigma_\alpha^2 . \qquad (28)$$

Assuming that $\sigma_\alpha = \eta/3l$ we obtain

$$\delta_{max} \simeq \frac{\eta^2}{3l}. \qquad (29)$$

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SOME INSPECTION PROBLEMS OF EYEGLASS OPTICS

G. I. Strakun

The efficiency of work and the quality of eyesight of people suffering from a correctable eyesight defect depends to a considerable extent on the accuracy with which these defects were determined, and on how well the optical qualities (refraction) of the spectacle glass satisfy its requirements.

The refraction properties of spectacle lenses are characterized not by their focal length f' but by the quantity $D = 1/S'$, where S' is the distance from the center of the lens surface facing the eye to the focus. If S' is expressed in meters then D describes the back center refraction expressed in diopters. This refraction of spectacle lenses is measured on devices called dioptrimeters, the scale of which is graduated in diopters. These measurements must make sure whether the lenses produced satisfy the requirements of the relevant GOST specifications which fix the permissible deviations from the nominal refraction. Naturally the measurement device, i.e., the dioptrimeter,is capable of producing reliable measurements and it should therefore be possible to have it checked.

Set of master lenses of the VNIIM for the calibration of dioptrimeters. Until recently dioptrimeters were checked more or less occasionally by methods which were not always accurate particularly with bispherical lenses. It is, however, known that with lenses having the same focal length f but different shape the top refractions can be substantially different. This phenomenon caused by different positions of the principal planes in each lens invariably introduces an additional error to the center refraction during the change from the focal length, measured by any type of focometer.

Plano-convex or plano-concave lenses represent, to some extent, an exception; the power 1/f and the center refraction of such lenses, determined with respect to the spherical surface, are equal. In order to determine the refraction of such lenses it is no longer necessary to carry out measurements by different methods on devices of different sensitivity, as used to be the case in testing bilenses which were used to test reference dioptrimeters; the focal length and, consequently, the center refraction can be accurately calculated if the radii of curvature of the spherical faces and the refractive indices of the glass of which the lenses are made are known.

The refraction of the glass of master lenses of the VNIIM, consisting of sets for testing the refraction scale of the dioptrimeters, is determined by the calculation method.

In this method the refraction index of the glass of which the lenses were made ($\Delta n_D = 5 \cdot 10^{-5}$) was determined, and 42 flat convex and 42 flat concave lenses were made of this glass. The required accuracy in the making of flat and spherical surfaces of the lenses was ensured by specifying close limits for the deviations of the lens radii from the radii of the specially made reference lenses, and for the local errors.

The deviations were measured by means of interference fringes of equal width produced by placing test plates onto the lenses being tested. The manufacture of 6 pairs of spherical test plates had one further purpose. It is known that in measuring the radii of curvature on a spherometer the equation also contains the radius of the spherometer ring and the measured deflection of the spherical surface. The larger the diameter of the test specimen whose radius of curvature is being determined, the larger is the radius of the measuring ring of the spherometer and, consequently, the larger is the absolute value of the deflection. The use as a basis for the measurement of the radii of curvature of test plates whose diameter exceeds by 1.5-2.5 times the diameter of the lenses being tested makes possible a reduction of the relative error occurring in the measurement of deflection, which results in a corresponding improvement of the accuracy obtainable in the determination of the radii. In working out the refraction of lenses the calculation contained the values of the radii of master lenses, including the correction for the deviation of the lens surfaces of the test plates. These deviations were determined during the acceptance tests on the manufactured lenses alongside with their checking for the absence of residual stresses and waviness in the glass.

As an example we give the calculation of the radius of curvature and refraction for the lens $\varphi = -0.5$ diopter from the No. 1 set.

During the measurement of deflection of the spherical surface of the master test plate its arithmetic mean was h_{def} = 0.8700 mm when the diameter of the ring of the IZS-7 spherometer was 2r = 84.940 mm, and the radius of the spherical supports was ρ = 4.988 mm.

After placing the lens on the corresponding spherical test plate a deviation equal to one interference fringe (a "hump" of 0.3 μ) was found, while the inspection of the flat face of the lens on a flat test plate showed a "hump" of 1.5 fringes (0.5 μ); in this case both deviations from the required form of the surface reduced the lens power, thus the deflection h_{def} should be reduced. Taking into account the difference between the areas of the lens being tested and the test plate (on the diameter of the spherometer ring) the deflection h_{def} was -3μ, i.e., the value of the deflection needed for the subsequent calculation was h_e = 0.867 mm.

Using the equation

$$R = \frac{r^2}{2h} + \frac{h}{2} - \rho,$$

where

r is the radius of the spherometer ring,

h is the deflection of the spherical surface; and

ρ is the radius of the spherical supports of the spherometer ring,

we obtain the radius of the lens

$$R_e = 1035{,}642 \text{ mm}.$$

The focal length of the lens made of a glass with the refractive index n_D is

$$f' = \frac{R_e}{n_D - 1} = \frac{1035{,}642}{1{,}51633} = 2005{,}776 \text{ mm}.$$

and the lens power $\varphi = 1/f'$ related to its spherical surface and expressed in diopters is

$$\varphi_{-0.5} = \frac{1000}{2005{,}78} = -0{,}499.$$

The refractions of other lenses were obtained in a similar way.

The use of the calculation method together with a definite method of production and inspection of lens surfaces made possible the determination of the back center refraction of test plates with an error of the order of 0.1%. Seven sets were made up of the 84 tested lenses and taken into use.

Each set consists of 6 plano-convex and 6 plano-concave lenses with the following nominal refractions: ± 0.5; ± 1.5; ± 4; ± 8; ± 14; and ± 20 diopters.

More accurate values of the refraction of these plates (up to hundreths of a diopter) are contained in the certificates attached to each set.

The test plates are fixed in their frames in such a way that the flat surfaces face toward the markings on the frame handles which show the nominal refraction. The fact that the marking always faces the observer who checks the dioptrimeter makes sure that the center refraction is determined with respect to the spherical surface.

The existence of a set of master lenses compiled by the above method not only made possible the laying of a foundation for the unified inspection of the refraction scale but also the sufficiently accurate selection of dioptrimeter types suitable for more accurate methods of checking spectacle lenses.

On some devices for the checking of spectacle lenses. It should be pointed out that suitable equipment is as yet not everywhere available for the inspection of spectacle lenses, i.e., of the optical devices most widely used in everyday life.

For example, hospitals and dispensing opticians very often use a simplified Zeiss dioptrimeter and similar equipment. A check showed that such dioptrimeters fail to ensure the measurement accuracy required today, and are difficult to operate. Attempts to correct the situation which has evolved over many years led to the construction of the Russian DO-2 model.

A recent tendency abroad is to use dioptrimeters with the refraction scale projected onto a screen, which makes the work of the inspector considerably easier. Even more advanced systems are available in which the projection method is supplemented by a correction of the refraction scale (German Democratic Republic).

It is most essential that if the organization distributing spectaclesuses only medium-accuracy dioptrimeters in many cases, then the makers of the lenses and the inspection organizations need dioptrimeters which, with respect to their versatility and accuracy, are devices of a higher class. Unforunately, the number of accurate dioptrimeters is very limited and by no means all the organizations which need such devices have them; the result is a lack of satisfactory inspection of spectacle lenses of various types and a shortage of sets of medical test lenses. At the same time, existing experience on the design and production of dioptrimeters could make possible a more satisfactory solution of the problem of checking spectacle lenses than is the case at present. It should also be taken into account that the production of optical equipment is increasing from day to day. Complex types, such as toric and other combined lenses can be tested, if at all, only under great difficulties on the majority of simplified dioptrimeters.

SUMMARY

Dioptrimeters should be divided into two groups. The instruments of the first group, the universal dioptrimeters, should be supplied to all plants producing spectacle lenses, and to the establishments of the Commission on Standards, Measures, and Measuring Instruments; more accurate dioptrimeters of the universal type especially selected from those instruments whose design meets the increased requirements can be used.

All organizations supplying the spectacle lenses direct to the users should be equipped with dioptrimeters of the second group. The precision with which these devices measure the refraction can be lower than that of more accurate dioptrimeters of the universal type, but the errors of indication of their refraction scale should not exceed the deviations from the nominal refraction of spectacle lenses specified in GOST

Thus, for a more effective inspection of spectacle lenses it is necessary to organize the large-scale production of dioptrimeters of increased precision. One of the Russian designs (State Optical Institute) or one of the most up-to-date foreign models could be taken as a basis for the new design.

DEVICE FOR THE INSPECTION OF DIAL GAGES

V. A. Chudov

During regular inspection of dial gages with a measurement range 0-10 mm, readings must be taken at 200 points (at 100 points during the forward motion of the plunger and 100 points during the return. Most frequently this inspection is carried out by means of a Zero-Glass micrometer in which the fixed anvil is replaced by a clamp for securing the dial gage. The productivity in working with a micrometer or wedge-type device with an optical or micrometer scale which is used for this purpose is low, because at each point, before the reading is taken, the pointer of the scale must be set at each division, and the reading taken on the scale of the gage being inspected.

The device described below makes possible a considerable increase in productivity during the checking of dial gages point by point, because it eliminates the most labor-consuming operations: the setting of the pointer to the required division and the taking of readings on two scales. This has been achieved by noting the angles through which a precision screw must turn to move the wedge over the required distance.

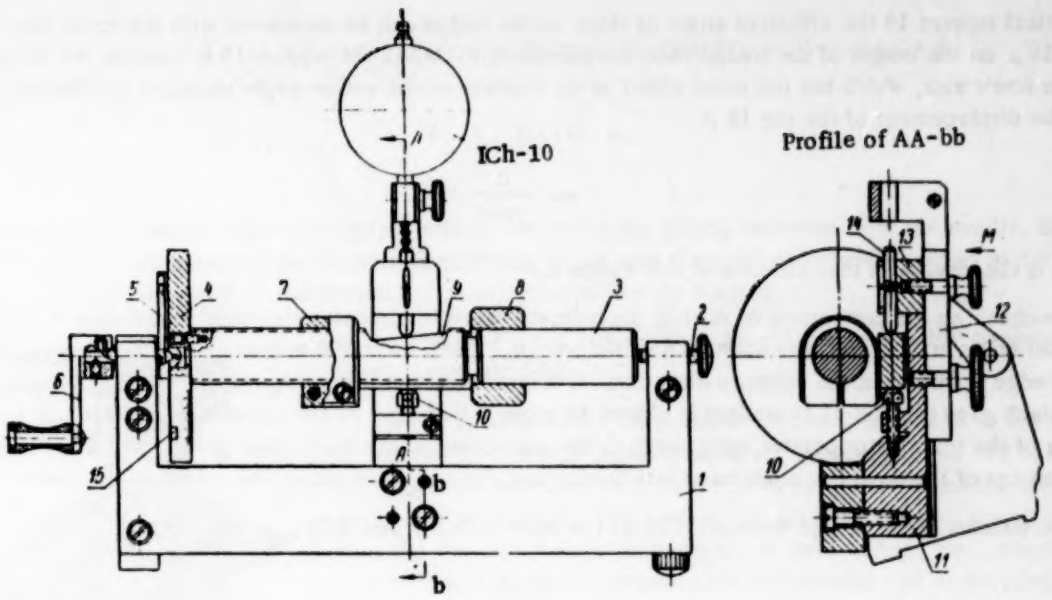


Fig. 1.

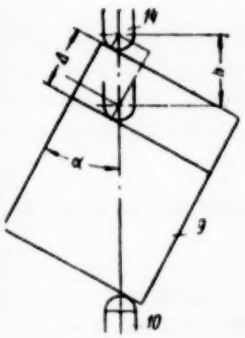


Fig. 2.

The adjustable centers 2 (Fig. 1) are mounted on the base 1 of the device; the screw 3 rotates between them. On the left the screw carries a Geneva-cross mechanism 4, the pin 5 of which is operated by the handle 6.

The adjustable split nut 7 is screwed on the screw 3 which also carries the smooth sleeve 8. The wedge 9 moves on the support 10 of adjustable height, and is screwed to the nut 7 and sleeve 8. The support 10 is secured to the upright 11 which in turn is screwed to the base 1 and carries the interchangeable support arm 12 for the dial gage being checked. The pin 14 moves in the block 13, its purpose being to relieve the indicator plunger of the radial forces produced by the wedge.

The slope of the wedge 9 is 1:10 when the dial gages with 0.01 mm divisions are inspected and 1:100 for dial gages with 1 μ divisions. The cross 4 has four teeth. The screw 3 has TRAP 27 x 4 thread. Thus, one complete turn of the pin 5 turns the cross through a quarter of a turn, the wedge moves through 1 mm and the pointer of the instrument being inspected should move exactly three divisions.

Before checking, the dial gage is set to zero with the pin of the drive moved out of the cross.

During the inspection the handle 6 is given one complete turn with the left hand, while the deviation of the pointer from the required division (the error of the instrument at a given point) is noted with the right hand. After the checking in one direction is completed, the error of the reverse direction can be recorded without any alterations in the setup, by turning the handle in the opposite direction.

The device can also be used for the inspection of dial gages with a diameter of 28 mm. In this case the other interchangeable support arm 12 is used.

When limit marker switches are checked, the Geneva mechanism is not used, and the screw is rotated by hand using the cross as the handwheel, until the contact of the switch is closed. In this case the reading is taken by means of the pointer 15 on the scale fixed to the periphery of the cross. The scale has 400 divisions with an interval of c = 0.8 mm; each division corresponds to the motion of the plunger through 1 μ, or to 0.1 μ travel, if a wedge of a different slope is used. The contact switch is secured to the third interchangeable support arm. In order to provide for a free rotation of the screw the Geneva mechanism is made without a lock.

Assuming that an error of the order of one division of the cross scale, i.e., 0.1 of a division of the instrument being tested, is permissible, the error of the screw pitch must not exceed 5 μ. By regulating the height of

the spherical support 10 the effective angle of slope of the wedge can be increased, with the result that an angle error of 10 μ on the length of the wedge becomes permissible. When the support 10 is lowered the wedge 9 turns about the screw axis, which has the same effect as an increase of the wedge angle since, as can be seen from Fig. 2, the displacement of the pin 14 is

$$h = \frac{\Delta}{\cos\alpha},$$

where Δ is the change in the thickness of the wedge 9.

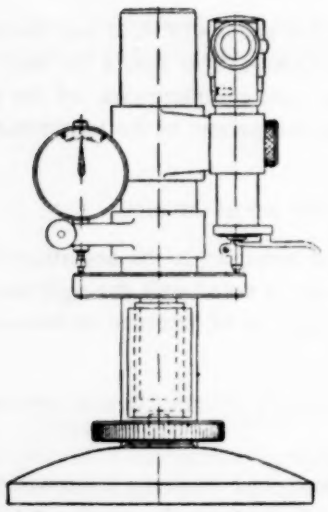
For checking the correctness of setting, an indicator gage (microcator, etc) with μ divisions is fixed in the device and set to zero against the wide face of the wedge. Then, after 100 revolutions of the Geneva mechanism pin the wedge is moved in the opposite direction. A 1 mm reference block gage (for the 1:100 wedge) or a 10 mm block gage (for the 1:10 wedge) is placed between the plunger of the microcator and the pin 14. If the deviation of the microcator pointer corresponds to the correction of the block gage given in its certificate, then the adjustment of the device is considered satisfactory and the support is locked by means of the screw.

The flatness of the wedge faces must be of the order of 0.5 μ and 0.05 μ, respectively.

CHECKING OF INDICATORS WITH 1-2 μ DIVISIONS

A. L. Zaikin

We successfully use in the Central Laboratory of our plant a vertical optical comparator for the inspection of dial gages with 1-2 μ divisions.



The essence of the method is as follows: the vertical optical comparator (see figure) is fitted with a support arm which carries the gage being tested. This arm is similar to the arm which carries the instrument tube. The arms are mounted on the stand of the instrument in such a manner that the plungers of the dial gage and the comparator touch the table plane.

As usual, the comparator scale is set to zero. The dial gage is set to zero approximately, and clamped in position. Thereupon, by turning the dial, the gage is also set to zero.

Further movements of the measuring plunger are effected by turning the nut of the component table.

The indications of the instrument are compared by observing the indications of their dials at the desired points.

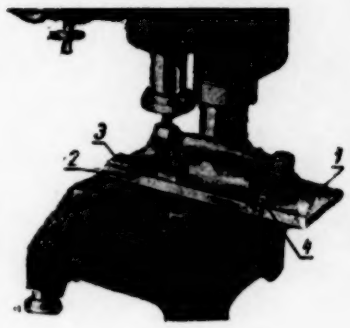
The minimeters can be checked on the vertical optical comparator in exactly the same way. The minimeter is set accurately to zero by means of the micrometer screw. The tube of the optical comparator is set to original position on any division of the scale against the reading which is close to the center of the scale, so that its deflections make possible the checking of minimeter indications on the entire dial in the plus and minus directions.

This method is simple, sufficiently accurate and efficient. In addition, with this method it is easy to determine the backlash of the inspected gages in the forward and reverse directions, immediately after the reversal of the plunger motion.

MEASUREMENT OF SMOOTH DOUBLE-ENDED PLUG GAGES

B. A. Kaliuta

For measuring double-ended plug gages without removing the gaging members from the handle, the Central Instrument Laboratory of the Buzuluk Engineering Works uses a special attachment (table) to the IZV-1 optical comparator (see figure); the device has been developed by the author.



The base 1 is a 105 x 240 x 12 mm plane-parallel hardened plate, knurled on both sides.

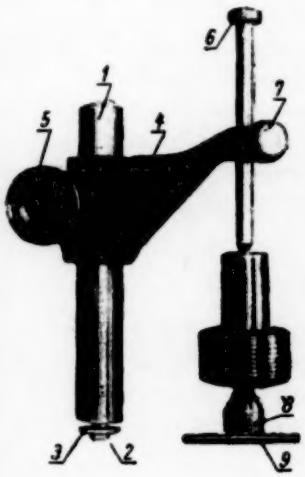
The hardened 12 x 18 x 100 mm plate 2 is secured to the base plate 1; its two 12 mm high parallel faces are lapped. At one end of the plate the edges are bevelled for a length of 40 mm, leaving on the top a 1 mm wide working surface. The sides of the plate have 3 mm deep grooves to take the brackets 3 with leather stuck to their bottom part. Another plate 4 of the same height is placed under the opposite end of the plug.

Before starting the work the base 1 is placed onto the table of the comparator and secured to it by means of two M5 screws; thereupon the plate 2 is placed into position, where it is loosely held by the brackets. After lowering the comparator plunger, with the instrument connected to the power supply, the plate is slowly moved to the right and to the left for finding the most favorable position on the scale of the instrument; thereupon the screws of the brackets are finally tightened, and the second plate placed onto the table underneath the second gaging member (plug) of the gage.

DEVICE FOR THE INSPECTION OF THE DIAMETERS OF SCREW THREAD PLUG GAGES

A. M. Startsev

The inspection of the pitch and outside diameters of screw thread plug gages on a horizontal optical comparator in a horizontal position is a very labor-consuming operation.



The author is using the "detachable centers" device (see figure) for the inspection of the pitch and outside diameters of screw-thread and smooth plug gages on a horizontal optical comparator in a vertical position without modifications to the comparator table.

The device consists of the vertical column 1, the screw 2 and the safety plate 3 for fixing the column 1 by its end face to the comparator table groove, the movable support arm 4, and the screw 5 for securing the arm 4 in the required position on the column 1; the support arm 4 takes the movable upper center 6 which is secured in the required position by means of the screw 7.

On the opposite side, the lower movable center 8 is introduced into the groove of the instrument table; it is screwed on a bar in the center of the stop plate 9 until the axes of the lower and the upper centers coincide, whereupon it is locked in position.

For inspection, the gage is mounted between the centers 6 and 8 and

secured by means of the screw 5, whereupon the inspection can proceed.

The device is simple to make, convenient in use, renders the work of the inspector easier and improves his efficiency.

PKG-1 AUTOCOLLIMATOR

E. L. Finkel'shtein

Angle gages in combination with autocollimators are increasingly being used for angular measurements (checking of ODG, ODS and other instruments).

The autocollimator used for this purpose has a focal length of 200-250 mm and utilizes an AM-9 micrometer eyepiece as the indicating device; the divisions of the micrometer ring scale which correspond to the angle through which the reflecting working surface in front of the autocollimator turns is 4-5". This accuracy is often inadequate.

Our optical industry is now manufacturing the PKG-1 autocollimator which has an accuracy of up to 1" in angular measurements.

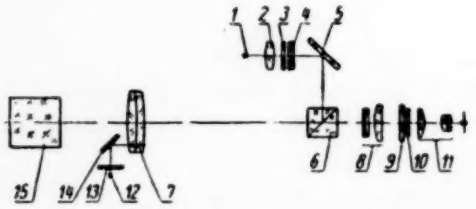


Fig. 1.

Figure 1 shows the optical system of this instrument, which has been developed by the author.

The light source consisting of the filament bulb 1 and the condenser 2 throws a beam through the green light filter onto the plate 4; two narrow mutually perpendicular slits forming a cross are cut in the mirror-silvered surface of this plate. The illuminated cross stands out sharp on the black background.

The width of the slit is chosen in such a manner that it represents a bisector with the vertical line of the micrometer inside it. The use of an autocollimator grid of this type makes possible an intense illumination of the slit (bisector) and at the same time greatly reduces the total amount of light entering the tube. This practically eliminates the dispersion of light inside the instrument and creates favorable conditions for obtaining a high accuracy of adjustment.

The rays coming from the luminous cross are directed by the objective 7 by means of the mirror 5 and the prism 6 on to the surface of the master prism 15.

Since the total distance from the luminous cross to the objective 7 is equal to its focal length, then the rays leaving the objective are concentrated into a parallel beam. After being reflected from the focused surface of the master prism 15, the rays are collected in the focal plane of the objective 7 where the optical micrometers 8, 9 and 10 are placed for determining the displacement of the image of the luminous cross caused by the turning of the reflecting plane in front of the objective. The lenses 11 belong to the eyepiece of the instrument. The bulb 12 illuminates the second arc scale in the field of view through the light filter 13 and the mirror 14 and is switched on only at the moment when the reading is made.

The principal special feature of the instrument being described is the use of an optical micrometer in place of a screw micrometer.

The lens compensator (Fig. 2) is used as the optical micrometer; it consists of the stationary lens 8a, the movable lens 8b which moves in a direction perpendicular to the system's axis, the optical scale 9 which is placed in the focal plane of the eyepiece, and the stationary indicator 10. The scale 9 is rigidly connected to the movable lens of the compensator unit 8b.

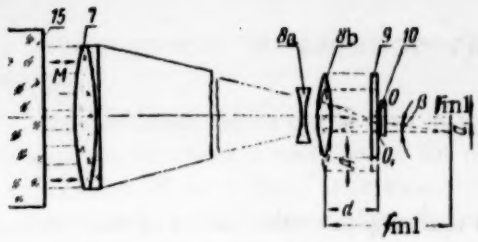


Fig. 2.

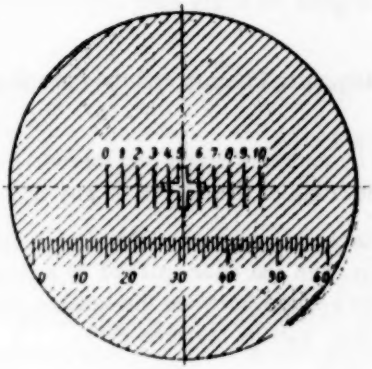


Fig. 3.

In the zero position the parallel beam of the light M which arrives in the objective parallel to its axis is concentrated at the point O.

When the movable lens of the compensator moves perpendicular to the axis (for example through the distance A) then the main ray of the beam after leaving the lens is bent through the angle β where $\beta = A/f_{m1}$ (f_{m1} is the focal length of the movable lens of the compensator).

In this case the image of the beam M moves from the point O on the axis of the system to the point O_1; $OO_1 = \overline{a} = \overline{d}\beta = A\overline{d}/f_{m1}$, where $\overline{d}$ is the distance between the movable lens and the image plane (focal plane of the eyepiece).

The displacement A of the lens is read on the optical scale 9 with respect to the stationary scale applied to the plate 10.

The field of view is illustrated in Fig. 3.

Eleven divisions of the arc-minute scale are reproduced in the central part of the field of view (plate 10, Fig. 2). When the instrument is in use the image of the autocollimator cross coincides with the lines of this scale. The number of full arc minutes is read on this scale.

Somewhat below the center of the field of view (plate 9, Fig. 2) is the scale indicating the displacement of the movable lens. It is graduated in arc seconds. The reading shown in Fig. 3 is 5'30.5".

By selecting the suitable focal length for the movable lens and the distance between this lens and the focal plane of the eyepiece, it is practically possible to obtain in the field of view any values of the angle divisions of the scale within the sensitivity of the tube, without increasing the focal length of the objective.

For example, with a 350 mm focal length of the movable lens of the compensator, a 14 mm distance between this lens and the focal plane, and the 400 mm focal length of the autocollimator objective, a 1" angle of turn of the working reflecting plane in front of the autocollimator will be produced by a 0.1 mm displacement of the movable lens of the compensator, i.e., the 0.1 mm divisions of the scale in the field of view will correspond to an angle of 1 arc-second.

The main advantages of the micrometer being described over the screw micrometer are as follows: high sensitivity (in our case with an eyepiece magnification of 20 x the sensitivity of the optical micrometer is 500 instead of the screw micrometer's 75); all scales are inside the field of view and can be read without taking the eye from the eyepiece; a compact design is obtained (the size of the tube for the same accuracy of reading can be reduced to a fraction of the earlier size); and the mechanism for moving the scale has no measuring functions and can therefore be manufactured by simpler methods.

The specification of the PKG-1 device is as follows: magnification 32 x, inlet opening 40 mm, focal length of the objective 400 mm, scale divisions 1', divisions of the precision scale in the field of view 1", measurement range 10', and sensitivity (double magnification) 64.

The indication error due to the error in the coincidence in the field of view of the image of the autocollimator slit with the vertical line is 1".

The device has a table carrying a rectangular prism the accuracy of whose angles is determined by the desired precision of the angle-measuring equipment to be inspected.

The applications of the device are not limited to the inspection of the ODG and ODS instruments for angular measurements. By adding an inclined mirror attached to the objective of the instrument it is possible to obtain an autocollimation from any suitable plane arranged in the space in any desired way.

In this manner it is possible to check the straightness of slideways, horizontals, verticals, etc.

DEVICE FOR CHECKING TRY SQUARES

S. M. Bereslavskii

External and internal try squares are usually checked with a master gage by the method of three try squares and double size of clearance.

These methods of inspection of angle gages have a number of disadvantages and cannot always be used.

The indicator device described here was developed by the author; it gives an angle error measurable in microns, improves efficiency and requires no master try square.

Two cast iron blocks 1 form the base of the device (Fig. 1); their length is 750 mm and they are joined by means of rivets and bushes connected by screws and nuts.

For greater stability the legs of blocks carry plates which are fixed by means of rivets and screws. Four screw-threaded pins are screwed into the plate; they enable a stable positioning of the device on any surface.

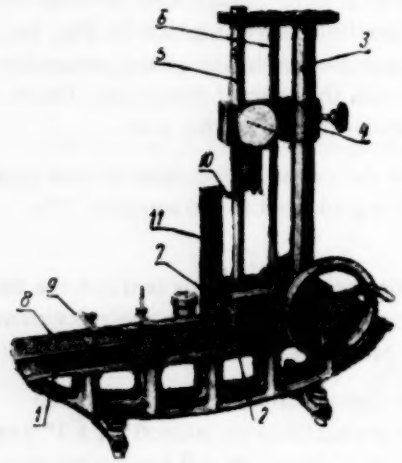


Fig. 1.

The top flat part of the blocks has grooves milled in a longitudinal direction; the grooves are 1 mm deep and wide, placed 20 mm apart; their purpose is to ensure a better contact between the squares and base blocks and to prevent dirt from getting between them.

The cantilever arm 2, which has four supporting legs, is screwed to the blocks 1 by means of four screws. It carries the hollow column 3; the slide 4 which carries the indicator graduated in μ moves along this column.

Another support 5 screwed into the arm 2 provides for the stability of the column 3.

The slide 4 can be moved on the column 3 by means of the screw 6 which is operated by means of a handwheel over a gear transmission incorporating bevel and spur gears.

The cylindrical roller stop 7 is fixed on the left-hand side of the arm 2 by means of two screws.

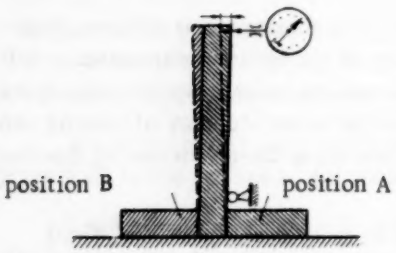


Fig. 2.

At a certain distance from the working edge a row of holes is drilled and tapped in the slideway 8; these holes take the clamp 9 used for fixing the try squares.

The slideway 8 is moved on the working surface of a ruleblock by means of a wing nut and eccentric which are mounted on a common shaft; the eccentric fits into a special hole in the slideway. In order to ensure that the slideway moves in one direction only, longitudinal keyways are cut on its ends. Keys placed into these keyways are secured to the surface of the ruleblocks by means of two screws.

The measuring plunger 10 is connected by a lever to the indicator.

The try square 11 being tested is mounted on the working surface of the blocks 1 and pressed against the slideways 8 and the cylindrical end stop 7 (position A in Fig. 2). Then the slide 4 is moved by rotating the handwheel until the plunger 10 touches the edge of the try square at a certain distance from its apex. At a definite distance the slide 4 is locked on the slideway 3.

Thereupon the position of the indicator pointer is set to zero by adjusting the scale.

Then the try square is turned through 180° and again secured in position B (Fig. 2) by pressing it against the slideway 8 and the stop 7, and the indicator reading is recorded.

The deviation of the try square from the perpendicularity is determined by the difference of the indicator readings.

The described device can be used for measurements on a length of 500 mm. If the long leg is longer than 500 mm then the check is made on the 500 mm length and the calculation provides the correction factor for the indications of the device; as an example we give the inspection of a try square with the length of the long leg H = 800 mm. The indicator of the device shows a deviation from perpendicularity of 0.05 mm on the length of 500 mm; the actual deviation on the 800 mm length is 0.08 mm.

DEVICE FOR THE PRODUCTION INSPECTION OF THE SURFACE ROUGHNESS OF PLATE GLASS

G. M. Gorodinskii

Plate glass is ground and then polished; the polishing removes the microirregularities which cause the dissipation and opacity of ground glass. The microstructure of the surface being ground must be continuously watched in order correctly to determine the time for the change from grinding to polishing.

For this purpose several glass works have been using for the past three years the flying reflectometer which is described here.

The principle utilized in this device is based on the variation of the composition of the light reflected from matt glass surfaces, which was first examined by Rayleigh. This phenomenon is due to the dissipation of light, depending on the ratio of wavelengths of the light flux falling upon the matt surface and the size of the microirregularities.

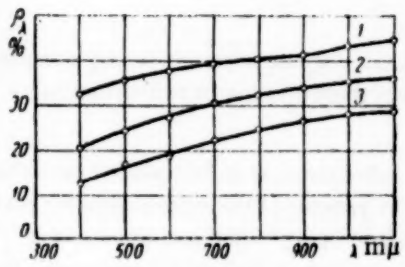


Fig. 1.

Figures 1 and 2 show the kind of variation of the composition of the spectra of the light reflected from the matt glass surfaces; these curves are plotted from the measurements made with an SF-4 spectrophotometer.

Figure 1 shows the spectral curves of the reflection factor ρ_λ for three matt glasses with different values of the average height H_{av} of microirregularities (No. 1 – 1.07 μ, No. 2 – 1.52 μ, and No. 3 – 2.13 μ) which were obtained on the IZP-5 profilograph. The curves show that ρ_λ depends to a considerable extent on the microscopic structure of the glass surface and decreases in the longwave region of the spectrum.

Figure 2 shows ρ_λ curves of these specimens for λ = 1000 mμ measured with the angles of incidence of the light varied from 76 to 86°; the curve 4 represents the reflection factor of a polished glass surface calculated from the formulae of Fresnel.

We obtained analogous curves for specimens made of other grades of glass.

The relations obtained permit the conclusion that the spectrum reflection factor of the relation of these factors for various sections of the spectrum, for example the "red-blue" relation, can be used as the qualitative and quantitative criterion of the roughness of a polished glass surface.

The flying reflectometer consists of the collimator and the receiving unit (Fig. 3). The collimator contains the incandescent lamp 1. The lamp is located in the focal plane of the achromatic objective 2 and its light passes through the iris diaphragm 3, rectangular prism 4, and the protective glass 5.

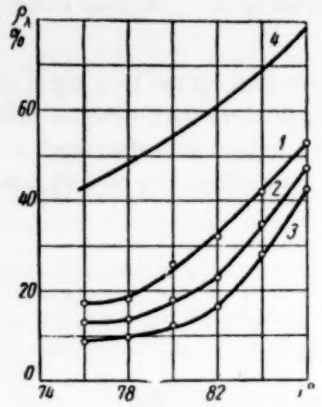


Fig. 2.

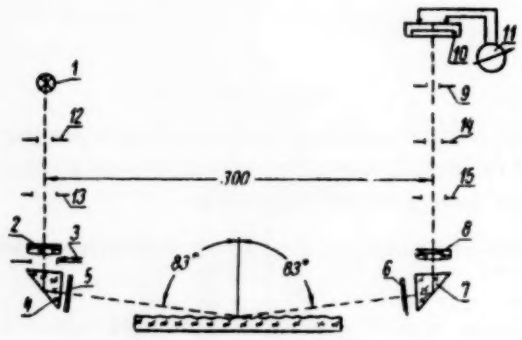


Fig. 3.

The almost parallel beam which leaves the collimator and whose cross section can be varied by means of the diaphragm 3 falls on the matt surface AB at an angle of 83°. The reflected beam passes through the protective glass 6 and the rectangular prism 7 and is collected by the objective 8 in its focal plane on the diaphragm 9, behind which a sulfur-silver photocell 10 is placed; the cell is connected to the microammeter 11. The surface of the photocell also receives a certain amount of dissipated light which corresponds to the rays dissipated by the matt surface within the angle of deviation of the "parallel" beam. Transverse diaphragms 12, 13, 14 and 15 are introduced to reduce the amount of parasitic light dissipated by the device.

In order to eliminate the visible part of the spectrum from the photocell a red light filter is used which at the same time serves for protection. The combination: filament lamp ($\lambda_{max} \approx 1\ \mu$), red light filter, and sulfur-silver photocell ($\lambda_{max} \approx 0.9\text{-}1.0\ \mu$) makes possible the isolation of a region in the infrared part of the spectrum.

The collimator and the receiving device are placed parallel to one another and secured to a block which is placed onto the glass surface when taking the measurements. The device has a casing to protect it from dirt. The M-91 microammeter is mounted on a separate panel which also contains the dc voltmeter, rheostats with their handles, sockets and terminals.

The lamp is connected to an accumulator battery. Provision is made to connect the lamp to an ac supply, which must be suitably stabilized. For the calibration of the microammeter scale a set of master specimens is supplied with the reflectometer.

The roughness of plate glass made by a certain process can be determined by three methods: by comparing the surface being examined with a master surface; by measuring the relative monochromatic reflection factor; and by the direct measurement of H_{av}.

For comparing the surface being tested with the master surface, the reflectometer is first placed onto the specimen, then, by opening gradually the iris diaphragm, it is set so that the pointer of the microammeter scale indicates 40-50 divisions. Thereupon the instrument is placed onto the surface being tested and the reading taken. In order to make the inspection easier the microammeter can be graduated in differences indicating the allowances for various grinding operations.

The measurement of the relative monochromatic reflection factor $\rho_{\lambda rel}$, which is equal to the ratio of reflection factors (i.e., of the corresponding photocell currents) of the matt and polished surfaces, is carried out as follows. The device is placed onto the polished surface and the maximum reading obtained on the microammeter scale by opening the iris diaphragm whereupon the device is transferred to the ground surface and the reading repeated. The roughness of the surface is determined from the tables of $\rho_{\lambda rel} - H_{av}$-curve compiled or plotted earlier.

For the direct determination of H_{av} the microammeter scale is graduated by means of master specimens with accurately measured microregularities. Since the microammeter scale is linear only within a narrow range of H_{av} values, a large number of specimens should be used in graduating the scale. In order to take into account the properties of the photocell and the light source, which change with time, the scale should be periodically checked.

The accuracy of measurements is determined by the accuracy of the method used in measuring the profile

of the specimens. In addition, the results obtained are affected by the stability of the light source and the accuracy of the reading of the microammeter scale.

During the calibration of test specimens it was found that within the H_{av} range 1.5-5μ, which is most frequently inspected, 2-3 divisions of the microammeter correspond to 0.1 μ.

MECHANICAL MEASUREMENTS

METHOD AND APPARATUS FOR CALIBRATION AND TESTING OF DYNAMOMETERS

O. N. Fofanov

The essence of the proposed method [1] is clear from Fig. 1. Here A and B are two dynamometers connected in series. A certain constant force P produced by a weight can be applied periodically at point p. Point q can be loaded with a force Q by means of any force machine.

The test is carried out by loading with forces, P, 2P, 3P ... nP.

On transference from some (i-1) stage of loading to the next higher (i) the following operations are carried out: 1) a force P is applied at point p; 2) a force $Q_{Bi} = (i-1)P$ is reproduced according to the reading $b_{(i-1)}$; 3) the reading a_i, corresponding to force $Q_{Bi} + P$, is noted; 4) the force P is removed and, according to the reading a_i, both dynamometers are loaded with a force $Q_{Ai} = iP$; 5) the reading b_i, corresponding to the force Q_{Ai}, is noted.

Here Q_A and Q_B denote the forces applied according to the readings of dynamometers A and B, and a_i and b_i denote their respective readings. The readings of the dynamometers in the process of unloading (reverse operation) are determined in a similar way.

The reproduction of forces according to this scheme involves certain errors, which arise in the change from one stage of loading to the other.

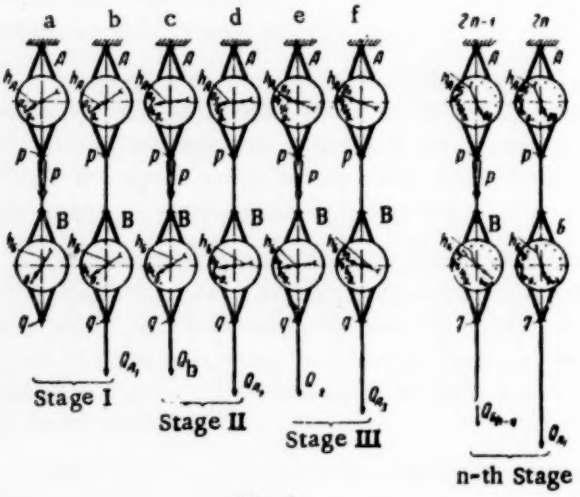


Fig. 1.

By using some constant load for producing the periodically applied force P, we can make the errors in the value and determination of P negligibly small in comparison with the errors permissible in the testing of dynamometers. Hence, with repeated loadings of the dynamometers we will obtain a scatter of readings due to the instability of the readings of the dynamometers themselves, and also to the fact that the values of the applied forces will vary within certain limits. The proposed method can be considered suitable in the case where the scatter of the readings a_i, b_i does not exceed the norm set for the dynamometers being tested and calibrated.

For an experimental investigation of the proposed method we constructed a KGM-5 machine rated for the reproduction of forces up to 500 kg. Its basic arrangement is shown in Fig. 2. The total weight of the periodically applied load P is equal to 500 kg. It was weighed in parts on a Class III standard equal-arm balance, which ensured that the error did not exceed 0.002%. In relation to the permissible errors of operational dynamometers (1-2%), the error in determining the force P can be considered as zero.

On KGM-5 we carried out tests of Class III standard and operational dynamometers. In investigating the

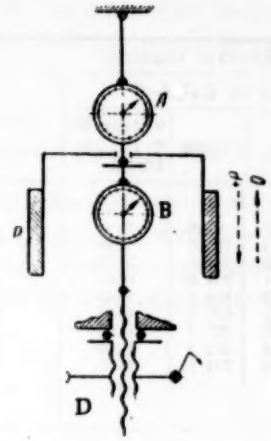


Fig. 2. A, B) Dynamometers under tests; P) constant load with mechanism for periodic loading; D) force machine.

TABLE 1

Force, kg	Variation as % of nominal (maximum) value of force			
	Dynamometer		Dynamometer	
	Direct loading	Reverse loading	Direct loading	Reverse loading
500	0.08	0.23	0.1	0.16
1000	0.32	0.25	0.01	0.17
1500	0.32	0.25	0.01	0.19
2000	0.33	0.3	0.1	0.27
2500	0.33	0.28	0.1	0.27
3000	0.35	0.22	0.1	0.33
3500	0.4	0.23	0.1	0.21
4000	0.32	0.26	0.1	0.1
4500	0.32	0.06	0.2	0.1
5000	0.26	—	0.06	—

scatter of readings of operational dynamometers we used a device which enabled us to take readings with an accuracy of 0.02-0.03 mm. As objects for the tests we used operational 5 ton dynamometers of the Schaeffer and Budenberg spring type, standard 5 ton dynamometers of the DK-5 type, LIMSKh and N. G. Tokar' dynamometers (DR and universal).

Tests of operational dynamometers showed that the results of checking on the KGM-5 practically concided with the results of a test carried out by the Committee of Standards, Measures and Measuring Instruments. The variation in the readings in cases of thrice-repeated loading on the KGM-5 did not exceed those permitted under Instruction 20-49.

As an example we give Table 1, which contains the data obtained in a thrice-repeated loading in the process of the simultaneous calibration of two dynamometers. The upper (A) was dynamometer No. 54326, and the lower (B) was dynamometer No. 57269.

According to Instruction 20-49 operational dynamometers are allowed variations of up to 0.5% of the maximum value of the force in direct and reverse loading.

Tests of standard dynamometers revealed that in a number of cases the variation of the readings in the first stage of direct loading and the last stage of reverse loading reached values of the order of 1% of the acting force. In the remaining stages the variation did not exceed 0.5% of the acting force. In Table 2 we give the data of the calibration of a Class III standard dynamometer No. 411 LIMSKh which was the upper one in the joint calibration with a N. G. Tokar' dynamometer No. 415. For comparison we give the rated characteristics of this dynamometer.

It should be noted that according to Instruction 20-49 standard dynamometers having a variation up to 0.5% are permissible for the checking of testing machines having an error no greater than ± 1%. Here the variation of the dynamometer, and also the error of the machine, are expressed as fractions of the force measured. Hence, it follows that the accuracy of calibration of standard dynamometers on the KGM-5 makes it possible to use them for the testing of operational dynamometers since the latter have a permissible error of ± 1-2% of the maximum value of the force measured. For instance, a five-ton Class I operational dynamometer has a permissible error of ± 50 kg, while the variation of 1% determined for a force of 500 kg in calibration on the KGM-5, is only 5 kg.

Thus, we have confirmed that it is possible to produce a machine for testing working dynamometers, which would have a constant force meter and a device for the periodic calibration of this force meter by a load of constant mass.

The proposed method enables us to calibrate the force meter of the machine for any force required in practice and then to carry out the testing and calibration of operational dynamometers according to its readings. In consideration of this we designed and constructed a KGM-50 machine for the testing and calibration of operational dynamometers up to 50 tons. It has the same basic arrangement as the KGM-5, but differs in construction and size.

TABLE 2

Force, kg	Direct loading						Reverse loading					
	Readings obtained on KGM-5					Nominal rating	Readings obtained on KGM-5					Nominal rating
	1	2	3	mean	variat. as % meas. force		1	2	3	mean	variat. as % meas. force	
0	0	0	0	0	0	0	0	0	0	0	0	0
500	84.1	83.4	83.4	83.6	0.85	84.8	84.9	84.6	84.2	84.6	0,83	85.9
1000	169.4	169.0	169.1	169.2	0.24	168.3	169.8	169.8	169.4	169.6	0.24	170.2
1500	251.8	251.0	251.0	251.3	0,32	251.5	252.0	252.1	252.0	252,0	0,04	253,3
2000	333.0	332.5	332.3	332.6	0.21	333.1	334.0	334.0	334.1	334.0	0,03	335.9
2500	412.7	411.8	412.0	412.2	0.22	413.1	413.0	413.0	413.3	413.1	0,07	415.5
3000	490.0	490.2	490.9	490.4	0.18	493.4	491.2	491.0	491.2	491.1	0.04	495.6
3500	569.8	570.1	570.7	570.2	0.16	574.9	571.0	570.9	570.9	570,9	0.02	577.7
4000	651.0	651.9	651.7	651.5	0.14	654.3	652.1	652.1	652.3	652.2	0.03	657.3
4500	733.0	733.1	733.6	733.2	0.08	734.9	734,2	734.2	734.6	734.2	0.05	737.6
5000	816.8	816.9	817.0	816.9	0.02	816.9	—	—	—	—	—	—

TABLE 3

Q	Direct loading			Reverse loading		
	a	σ_a	Δa_{max}	a	σ_a	Δa_{max}
0	0	0	0	0	0	0
5	70.9	0.14	0.3	71.8	0.44	0.8
10	141.6	0.27	0.5	142.0	0.41	0.9
15	211.7	0.29	0.6	212.2	0.45	0.8
20	282.3	0.42	0.8	282.7	0.57	1.1
25	354.4	0.50	0.8	354.6	0.62	1.3
30	425.4	0.49	0.8	425.5	0.49	0.9
35	496.8	0.57	1.2	496.9	0.51	1.0
40	567.8	0.60	1.0	567.9	0.52	1.3
45	639.3	0.54	1.2	639.4	0.54	1.3
50	710.6	0.50	1.2	—	—	—

Note. Q) Nominal value of acting force in ton; a) reading of dynamometer A (arithmetic mean of 15) in indicator divisions; σ_a) mean square deviation of readings of dynamometer A in indicator divisions; Δa_{max}) maximum deviation from arithmetic mean in indicator divisions.

The method of working with the machine consists in comparing the readings of a previously graduated dynamometer A with the readings of the operational dynamometer under test. Dynamometer A acts as the stationary force meter of KGM-50. For its periodic calibration there is a second similar dynamometer B, which is removed after the calibration is made; the operational dynamometers under test are put in its place. The results obtained from 15 repeated tests in the calibration of dynamometer A by means of dynamometer B are given in Table 3.

We can see from Table 3 that the maximum deviation from the mean, expressed as a percentage of the maximum force, is

$$\eta = \frac{1.3}{710.6} \cdot 100 = 0.18\%.$$

Assuming that in reproducing forces from the readings of dynamometer A we may allow an error equal to three times the value of the greatest of the mean-square deviations for all stages of direct and reverse loading, we obtain the maximum error

$$\eta_{max} = \frac{3 \cdot 0.62 \cdot 100}{710.6} = 0.26\%.$$

TABLE 4

Force, ton	Direct loading						Reverse loading					
	Readings obtained on KGM-50					Nominal rating	Readings obtained on KGM-50					Nominal rating
	1	2	3	mean	variat. as % meas. force		1	2	3	mean	variat. as % meas. force	
5	54.7	54.7	54.7	54.7	0.0	55,0	55.1	55,2	55,3	55,2	0;36	55.0
10	108.3	108.3	108.4	108.3	0.09	109,0	108.8	108.8	108.9	103,8	0.09	109.0
15	161.3	161.3	161.5	161.4	0.12	162.3	161.9	161.8	162.0	161.9	0,12	162.5
20	213.3	213.2	213.2	213.2	0.05	214.3	213.4	213.3	213.6	213.4	0,14	214.5
25	263.4	263.5	263.6	263.5	0.08	264.9	263.8	263.9	264.0	263.9	0.08	265.0
30	312.0	312.1	312.2	312.1	0.06	313.5	312.2	312.1	312.3	312.2	0,06	313.8
35	361.2	361.2	361.2	361.2	0.0	363.0	361.4	361.2	361.3	361.3	0,2	363.0
40	409.2	409.3	409.3	409.3	0.02	411.1	409.2	409.2	409.2	409.2	0.0	411.2
45	456.8	456.9	457	456.9	0.04	458.7	456.5	456.6	456.5	456.5	0.1	458.5
50	501.8	501.9	502.1	501.9	0.06	503.7	—	—	—	—	—	—

Dynamometers which should be tested and calibrated on KGM-50 have a permissible error $\delta_{dyn} = 1\%$ of the value of the force for which they are designed. A test of operational dynamometers from the readings of dynamometer A will be applicable on condition that

$$\eta_{max} < 0{,}3\delta_{dyn}$$

which is met at all stages of direct and reverse loading.

In Table 4 we give the characteristics of a Class III standard dynamometer No. 66, according to the data of the Sverdlovsk Office of VNIIM, and the data obtained by the repeated reproduction of forces from readings of dynamometer A. The good agreement of the results is a further confirmation of the accuracy of calibration on the KGM-50 by the method described.

A PRECISION ELECTRIC STRAIN GAGE FOR THE MEASUREMENT OF TRANSVERSE STRAINS

A. V. Gur'ev

The described strain gage was designed and constructed in the Stalingrad Mechanical Institute as part of a plan of research into transverse strains in metals.

Longitudinal strains were measured with a highly sensitive strain gage with scale division of 0.1 μ [1]. Since the relative transverse strains are approximately a quarter of the longitudinal, and the base of the strain gage for measuring longitudinal strains is 5 times the diameter of the specimen – 10 mm – then to ensure the same accuracy the magnification coefficient of the strain gage would need to be 20 times greater than that of the longitudinal strain gage, and it would have to have scale divisions of 0.005 μ.

We know that electric strain gages with a capacitance transducer are capable of measuring displacements of that order or less, but owing to their great complexity and instability, capacitance instruments have not yet obtained any degree of extensive application. In order to reduce the capacitive reactance of the transducer, high-frequency electronic generators are employed and this considerably complicates the instrument and raises its cost. The drawbacks of the capacitance apparatus include the effect of instability of the electron tube characteristics, its sensitivity to fluctuations of the supply voltage and the necessity to employ an oscillograph or sensitive galvanometer.

These drawbacks have been largely eliminated in the suggested design of strain gage. The basic technical characteristics of the instrument are: scale division 0.005 μ; upper limit of measurement 10 μ; base 10 mm (corresponding to diameter of test specimen); power consumption 30 w.

For increasing the sensitivity of the strain gage and obtaining a more uniform scale the capacitance transducer has three flat plates (Fig. 1). To reduce the weight the cover 1 and casing 2 are made of duralumin. The nut 3 retains the two rigid metal disks 4, between which insulation rings are mounted. The movable rod 4 carrying a ball at the end and attached to the central metal disk rests under the action of a weak flat spring 6 against the adjusting screw 7. The thickness of the insulating rings is chosen so that the air gap between the disks is equal to 0.2 mm. Rod 5 moves freely in the bronze sleeve 8.

Mounting the gage on the specimen for the measurement of transverse strains is effected by means of an attachment 9 (also acting as strain doubler), the legs of which are made in the form of the letter Г. This attachment automatically ensures reliable centering of the specimen. The legs of the doubler are connected by a flexible hinge in the form of a flat spring. The screened leads 10 are connected to the outer and central disks.

We know that the effect of supply voltage fluctuations may be eliminated if readings are taken with a

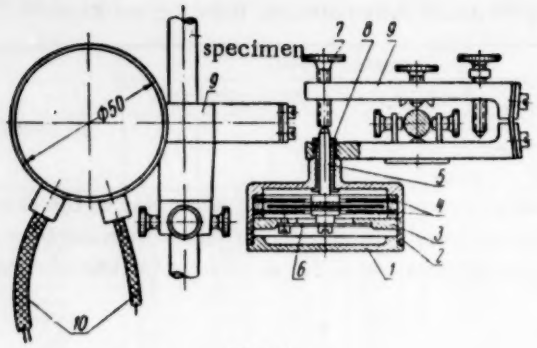


Fig. 1.

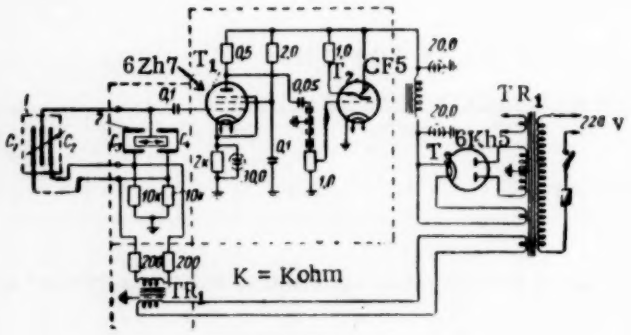


Fig. 2.

fully balanced bridge. For this purpose a balancing attachment 2 is introduced into the circuit of a secondary instrument (Fig. 2). When the specimen is strained there is a displacement of the middle plate 1 of the gage, thus leading to a change of the capacitance C_1 and C_2. The voltage in the diagonal of the bridge is amplified by the first electron tube T_1 and applied to a zero indicator, which consists of a tube 6E5. If the condition

$$C_1+C_4=C_2+C_3. \qquad (1)$$

is fulfilled, the voltage applied on the grid of the tube 6E5 will be zero and, hence, the dark sector of the indicator eye will be completely revealed. In this position the readings are taken. When the specimen is strained further the bridge is unbalanced again, and this produces a contraction of the eye owing to the application of a negative voltage on the grid of tube T_2. By turning the tuning knob of the instrument, the inner cylinder of the balancing attachment is moved until the eye is completely open, and the reading is taken again. The employment of manual tuning in the case of slow deformation or periodic loading (as usually happens in static tests) occasions no difficulties, but has the great advantage of permitting an extension of the scale, and, hence, of increasing the number of readings. In this instrument one hundred divisions are marked on the circumference of the dial of the micrometer screw which causes the movement of the inner cylinder of the balancing attachment, and the number of complete rotations of the dial is 20. Hence, in the measurement of strain we can take 2000 reliable readings, which is equivalent to a straight scale of length 2 m. Besides facilitating reading, the use of a 6E5 tube instead of a sensitive galvanometer allows a considerable simplification of the electrical circuit, since only one stage of amplification of the signal provides adequate sensitivity.

The bridge is supplied from a transformer Tr_2 with a current of industrial frequency at voltage 100 v, without the use of a high-frequency generator. The employment of the balancing attachment enables us to do without the voltage stabilizer. It was established experimentally that voltage fluctuations in the lighting circuit in the range 190-230 v had practically no effect on the strain gage readings.

In designing the strain gage the value of one division (on the dial) can be computed approximately from a formula deduced on the basis of (1):

$$m=\frac{a^2}{737\ S \lg \frac{D}{d}}, \qquad (2)$$

where a is the distance between the middle and outer disks of the capacitance transducer; S is the area of one side of the capacitor plates; D is the internal diameter of the outer cylinder of the balancing attachment; d is the external diameter of the inner (movable) cylinder of the balancing attachment.

In the design of the strain gage special attention was given to ensuring ease of operation, since this largely determines the degree of fatigue experienced by the operator, and, hence, of the occurrence of accidental errors. The tuning knob of the balancing attachment is brought out on the side of the secondary instrument, and the scale is inclined at an angle of 60° to the horizontal. Readings in divisions are made from the dial, and complete turns of the dial are marked on a horizontal scale by a travelling indicator. The dial and scale are illuminated by small lamps concealed from the observer's eye. The upper panel is provided with an inclined

tube carrying a magnifying glass for convenience in observing the eye of the indicator tube 6E5. The sensitivity control knob (left) and switch (right) are mounted on the same panel.

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MOVABLE OSCILLOGRAPH EQUIPMENT

A. M. Arodzero and E. I. Lakh

When an oscillograph is used for recording stresses in traction engine fields and especially road tests, special precautions must be taken to protect it from vibration and shocks.

With the object of better utilization of measuring equipment in field tests of engines the Central Scientific Research Institute for Mechanization and Power in the Lumber Industry produced a truck-mounted oscillograph installation. The equipment is mounted in the body of a specially fitted passenger bus T-82 made by "Giprolesmash" mounted on a ZIL-150 chassis; connections to the engine under test are made by means of a flexible cable.

The main components of the truck-mounted installation consist of oscillograph OT-24-51 made by the "Geofizika" plant, a control and balancing unit for measuring bridges, a distribution board for the supply circuits, storage batteries, a selenium rectifier and, a battery charging board. In addition the installation contains a bench with a vice and fitter's tools and a dark room for developing oscillograms in the dark or with red light in the course of testing.

A drum with a multicore cable and a bracket for supporting the cable are mounted in a casing on the back outside wall of the body of the vehicle.

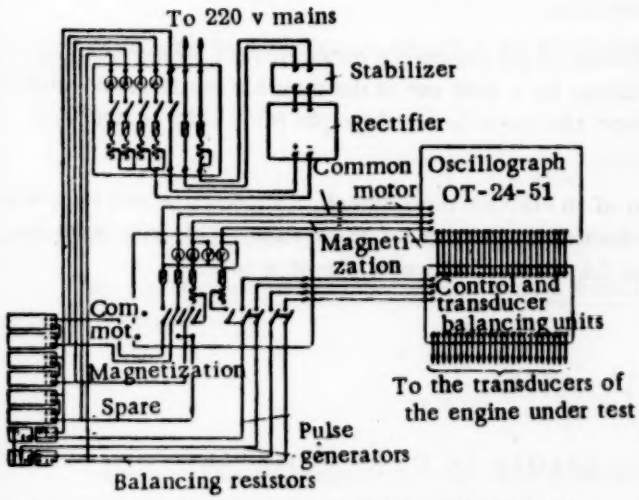

Diagram of measuring instrument connections in the truck-mounted oscillograph installation of the TsNIIME.

All the instruments and equipment are mounted on welded angle-iron stands fixed to the body of the bus.

In order to decrease vibration effects, the oscillograph and all the other instruments are mounted on rubber cushions. The oscillograph and the control equipment board are placed along the side windows of the bus so that the tester standing near the oscillograph can clearly see the section of the road over which the vehicle under test is moving. A hermetically sealed storage battery compartment is placed in the front portion of the bus; the compartment contains six twelve-volt and four six-volt lead storage batteries of 128 and 98 amp/hr capacity, respectively. The storage batteries feed the oscillograph circuit (magnetization, film propelling motor, lights and galvanometer heating) pulse generators, the balancing board, signal lamps and the bus lighting. For the escape of gases formed during charging, the battery compartment has a ventilating window with a hermetically closing lid. The batteries can be charged without removal from their compartment and without disconnecting any leads. A battery-charging plant

is mounted in the upper front part of the bus; it consists of a rectifier and a board with switches, ammeters and rheostats for controlling and measuring the charging current of various battery groups. The BSA-4 rectifier works from 127 and 220 v ac mains supplying a charging current of 24 amp at 25 to 28 v.

The rectifier mains socket is mounted on the outside of the bus body. The ac circuit includes a control rheostat. For mains working of the oscillograph a voltage stabilizer is provided.

The front wall of the bus carries a distribution board for switching-in and measuring the oscillograph supply current and for switching-in the balancing unit instruments. The board has rheostats for adjusting the oscillograph magnetizing and illumination currents.

The control and balancing unit is mounted next to the oscillograph. The transducers, connected in an even ratio bridge circuit, are balanced and their resistance measured by means of a ten-position switch, a portable galvanometer (for approximate balancing) and balancing resistors. Precision balancing is carried out by means of the appropriate oscillograph galvanometers. The peculiarity of the balancing circuit consists in the separate supplies to the transducer bridges and the balancing potentiometers. This arrangement reduces the number of conductors required in the multicore cable connecting the test installation to the engine under test. The control and balancing unit also contains jacks for a timer, tumbler switches, multiplier resistors of the pulse generator circuit, voltmeters, and a signal lamp which lights when the junction cable is connected to both the test installation and the tested engine, i.e., when the transducer balancing unit circuit is completed.

The balancing unit is connected to a 20 conductor 5 m-long lead-out cable, which ends in a 20 contact plug. During tests this cable is taken outside the bus and fixed by means of wooden clamps to the swinging bracket mounted on the side wall of the bus. During tests the lead-out cable is extended by means of a connecting cable.

For tests in cold weather a stove is provided.

During tests the oscillograph installation remains stationary in the middle of the test section. With a connecting cable length of 160 to 170 m the test section length can reach 300 m.

Tests of lumber-carrying automobile trains made by means of the movable oscillograph installation under various conditions were found to be accurate and reliable.

The use of this installation reduced considerably the time required for preparing the tests of traction engines and provided high quality oscillographic records, since it eliminated the interference caused in a sensitive oscillograph by the shocks during the movement of the vehicle.

Convenient accommodation and equipment consisting of the measuring instruments, a powerful storage battery, dark room and tools provide the required conditions for a wide use of the movable oscillograph equipment for engine tests with different measuring instruments (for instance oscillographs PO-6 1956 or POB-9) if required.

The installation can be extended by the addition of an electron oscillograph, a stroboscope and associated equipment for recording radio-transmitted test signals from the engines under observation. This will make the installation more independent and will greatly increase the volume and scope of engine tests.

EFFECT OF MANUFACTURING ERRORS IN DYNAMOMETER DISC SPRINGS ON THEIR RIGIDITY

E. I. Felikson

Disc springs (Fig. 1) used in large weight and power-measuring instruments as dynamometer elements must possess a given rigidity.

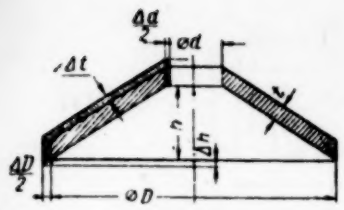

Fig. 1.

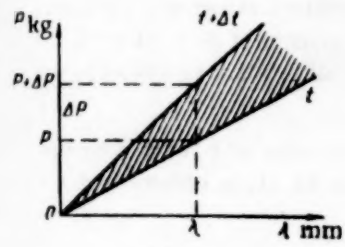

Fig. 2.

Owing to manufacturing errors in spring dimensions t, h, D and d the rigidity of springs deviates from the calculated value which leads to additional errors and impedes the adjustment of the transmission mechanism of the balance.

The effect of a manufacturing error in each dimension of the disc spring can be calculated by partial differentiation of Eq. (1), which expresses the relation between the load and the sagging of the spring in terms of its dimensions:

$$P = \frac{4Et\lambda}{(1-\mu^2)D^2A}\left[(h-\lambda)\left(h-\frac{\lambda}{2}\right)+t^2\right], \qquad (1)$$

where P is the effort exerted on the spring,

E the modulus of elasticity,
t the thickness of the spring wall,
λ the axial displacement of one disc,
μ the Poisson coefficient,
D the external diameter of the spring,
h the height of the unloaded spring measured as the height of a truncated cone formed by its external or internal surface,
d the internal diameter of the disc spring,
A is a constant given by the function of the ratio of the external to the internal diameter of the spring (m = D/d) and obtained from the graph in [1].

Let us determine the variations of load P at a constant λ (Fig. 2) caused by deviations of each of the spring dimensions t, h and D from their calculated value by Δt, Δh and ΔD. Dimension d is a 2nd grade fitting dimension and we assume it to be for our calculations d = const.

Effect of the deviation of the wall thickness (t) from its calculated value. Let us take a partial derivative of (1) with respect to t:

$$\frac{\partial P}{\partial t}\,dt = \frac{4E\lambda}{(1-\mu^2)\,D^2A}\left[(h-\lambda)\left(h-\frac{\lambda}{2}\right)+3t^2\right]dt.$$

Substituting the differentials dP and dt by finite small values of errors (respectively by ΔP and Δt) we obtain

$$\Delta P_t = \frac{4E\lambda}{(1-\mu^2)\,D^2A}\left[(h-\lambda)\left(h-\frac{\lambda}{2}\right)+3t^2\right]\Delta t, \qquad (2)$$

where ΔP_t is the variation of load P due to the deviation of dimension t by a quantity Δt.

Effect of the deviation of the spring height h from its calculated value. Let us take a partial derivative of (1) with respect to h:

$$\frac{\partial P}{\partial h}\,dh = \frac{4Et\lambda}{(1-\mu^2)\,D^2A}\left[\left(h-\frac{\lambda}{2}\right)+(h-\lambda)\right]dh.$$

Replacing the differentials by errors and transforming the expression in brackets we obtain

$$\Delta P_h = \frac{4Et\lambda}{(1-\mu^2)\,D^2A}\left(2h-\frac{3}{2}\lambda\right)\Delta h, \qquad (3)$$

where ΔP_h is the variation of load P due to the deviation h by Δh.

Effect of the deviation of the spring diameter D from its calculated value. Differentiating (1) with respect

to D and substituting the differentials by their finite error values we obtain

$$\Delta P_D = -\frac{4Et\lambda}{(1-\mu^2)D^3A}\left[(h-\lambda)\left(h-\frac{\lambda}{2}\right)+t^2\right]\Delta D, \qquad (4)$$

where ΔP_D is the variation of load P due to the deviation of dimension D by ΔD.

The different signs of the errors show that if an increase in h and t cause a rise in force P with a constant λ, an increase of D will cause a fall in P under the same conditions.

For springs used in crane balances PK-5 (maximum load 5 tons) with the calculated values of t = 9 mm, h = 4.5 mm, D = 202.4 mm, d = 41 mm, λ = 1.75 mm, and with manufacturing tolerances of Δt = 0.1 mm, Δh = 0.1 mm and ΔD = 0.1 mm, we obtain from (2), (3) and (4) that ΔP_t = 138 kg, ΔP_h = 31.2 kg and ΔP_D = − − 2.2 kg.

For determining deviations $\Delta\lambda$ in the sagging of the spring from its calculated value of λ, caused by the deviations of dimensions t, D and h from their calculated values it is possible to use Eq. (1) in which P and λ should be changed for ΔP and $\Delta\lambda$, respectively, or to use a simpler relation

$$\frac{P}{\lambda}=\frac{\Delta P}{\Delta\lambda}, \qquad (5)$$

which is sufficiently accurate for disc springs with a parameter ratio of h/t = 0.25 to 0.5 which makes their characteristic almost linear [2].

Rigidity tests of a consignment of paired dynamometer disc springs gave different values for deviations of λ which agreed well with the results obtained from calculation by means of the above formulas.

SUMMARY

In manufacturing dynamometer disc springs special attention should be paid to the accuracy of the wall thickness t. The external diameter of spring D has the least effect of the stiffness of the spring. Errors in the height of spring h in their effect on the stiffness of the spring occupy an intermediate position.

Formulas (2), (3) and (4) provide a measure of the stiffness deviation of the spring due to inaccuracies in its manufacture and establish permissible tolerances of the disc spring dimensions.

LITERATURE CITED

[1] S. D. Ponomarev, "Belleville's Disc Springs" Engineering Encyclopedic Handbook [In Russian] (v. 2).

[2] E. I. Felikson, Measurement Techniques, No. 4 (1957)[USSR].

A DEVICE FOR DYNAMIC CALIBRATION OF PIEZO-ELECTRIC PLATES

A. N. Chalyi-Prilutskii and B. E. Bolotov

Owing to their easy calibration induction, capacity and resistance transducers are widely used in industry. Many of these transducers are large and heavy and will only operate in certain positions. All these difficulties, as a rule, can be eliminated in piezo-electric transducers.

Oscillograms of vibrations obtained by means of piezo-electric transducers showed that unless their frequency of characteristic is taken into account they do not give a true picture of the vibrations.

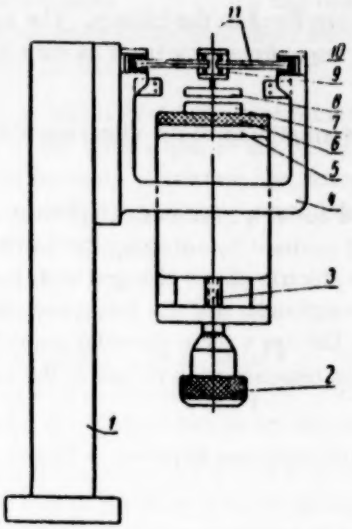

Fig. 1. 1) Stand with a base; 2) screw head; 3) screw; 4) bracket for fixing the micrometer device; 5) moving carriage for tuning the transducer; 6) plastic packing; 7,8) plates of the capacity transducer; 9) collar; 10) rubber packing; 11) piezo-electric plates.

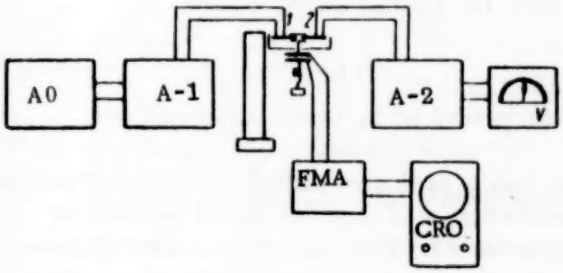

Fig. 2.

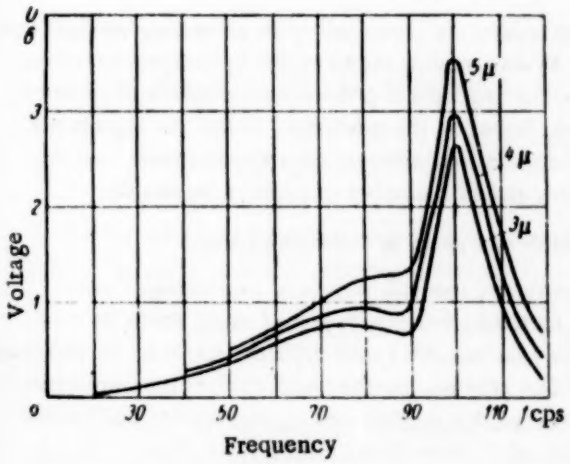

Fig. 3.

We describe below a device (Fig. 1) and methods we developed for obtaining a dynamic characteristic of piezo-electric plates. The basic experimental work was done with Rochelle salt plates; however, the device and method can be used for any piezo-electric plates.

One of the piezo-electric plates 11 serves as a generator, while the other is being tested. Both plates are fixed in a cantilever manner by means of rigid packing and placed in the same plane. The free ends of the plates are fixed to each other by means of an elastic collar 9 to which the upper plate of the capacity transducer 8 is also fixed. The lower plate 7 of the transducer is fixed to the insulated disc 6 mounted on moving carriage 5.

By means of this device we measured the intensity of polarization with respect to the excitation frequency of the piezo-electric plates at a constant amplitude. This relation plotted as voltage against frequency constitutes the frequency characteristic of the piezo-electric plate.

The operation of the whole system is based on the principle of the convertability of the piezo-electric effect. The reversed piezo-electric effect consists in the phenomenon that if an ac voltage is connected to the piezo-electric plate it will oscillate at the frequency of that voltage.

The voltage obtained from the audiofrequency oscillator AO was fed through the low frequency amplifier A-1 to the piezo-electric plate 1 (Fig. 2). Plate 1 oscillated and being rigidly connected to plate 2 made the latter oscillate as well. Piezo-electric plate 2 produced a voltage which after amplification in amplifier A-2 was measured on the millivoltmeter.

Since the oscillator and the audio amplifier have their own frequency characteristics the amplitude of the collar and, hence, that of the crystal plate ends had to be maintained constant. The capacity transducer was used to measure the amplitude of the plate vibrations. Plate 8 vibrated (Fig. 1) together with collar 9, plate 7 remaining fixed. The distance between the plates is thus changed by the value of the amplitude of vibrations.

The capacity transducer was connected to an oscillograph through a frequency modulated detector-amplifier FMA (Fig. 2).

It is possible to calibrate the capacity transducer statically. It was, therefore, calibrated by means of the micrometer device. Plate 7 of the capacity transducer (Fig. 1) was moved by means of screw 3 and knob 2 known distances and the differences in reading on the cathode ray oscillograph noted.

For obtaining frequency characteristics the piezo-electric plates were fixed to the holders. The exciting plate was mounted on one side and the measured one on the other. The lower frequency limit of the run was determined by that of the audio oscillator.

The test frequency was by the audio oscillator. The frequency and amplitude of the vibrations was recorded on the oscillograph by means of the capacity transducer 7,8 (Fig. 1).

In order to increase the test frequency range the testing was carried out at a minimum amplitude whose value was measured by means of the capacity transducer and maintained constant by adjusting the oscillator output; this was necessary since the amplitude of vibrations of the piezo-electric plates changed with frequency. Thus, the voltage at the output of A-2 was measured at several constant amplitudes and the frequency characteristic was plotted (Fig. 3). For frequency characteristics higher than 120 cps a more powerful amplifier should be used. All the curves (Fig. 3) have the same shape and their first resonant peak occurs at the same frequency.

Above results were obtained with piezo-electric plates at various temperatures between + 19 and + 35°C. The readings were not affected by the temperature variations.

Correcting for possible distortions. In order to avoid any distortions in measurements it is necessary to check the frequency characteristic of amplifier A-2 and correct the results accordingly.

MEASUREMENT OF DENSITY AND SPECIFIC WEIGHT OF SUSPENSIONS, BOILING LAYERS, LIQUIDS AND GASES IN ASCENDING FLOW

G. A. Adamov

In the various applications of suspensions, i.e., suspended and, in particular, boiling layers of small particles it is necessary to determine their density or specific weight and the change of these parameters both with respect to the height of the layer, and at consecutive times. In practice it is very important to be able to observe and measure directly the change of density or specific weight. For instance, direct measurement of suspension densities is of great importance in the gravitational concentration of coal and ores, a process in which suspensions are extensively used.

In a large number of cases suspensions, including boiling layers, are produced by an ascending vertical flow of gas or liquid. Measurements by means of a hydrometer, or by any modifications of the hydrostatic balance, are possible only where there is no ascending flow; when an ascending flow is present such methods of measurement are inapplicable owing to the action of aerohydrodynamic forces on the submerged body. As regards the sampling method, it is inconvenient, does not allow direct determination, observation and continuous control of the values being measured, is not always sufficiently reliable, and in a number of cases is unsuitable.

It is often necessary also to determine the density of liquids and gases in ascending flow.

Below we suggest a simple method of measuring the density and specific weight of suspensions – aero-suspensions and hydro-suspensions, and all kinds of suspended, including boiling, layers of small particles – in conditions of an ascending vertical flow (the speed of which may be variable) with different states of the medium, and which eliminates the effect of aerohydrodynamic forces.* The proposed method also enables measurements of the density and specific weight of liquids and gases. By means of this method and an appropriate calibration of the instrument we can determine directly the specific weight of a suspension (boiling layer, liquid, gas) γ_c

*The measurements are possible in any suspended layer constituting a pseudoliquid (including boiling layers in a state of pseudo-liquefaction), the density of which is a characteristic physical magnitude, i.e., with not too small a volume concentration of the disperse phase.

or its bulk density $\rho_c = \gamma_c / g$ and their variation (g is the gravitational acceleration). This method is of particular value for measurement in an ascending flow, for which it is mainly intended, but it is also valid in the case of absence of flow.

Two bodies of strictly determined shape are suspended on opposite arms of a sensitive balance and are submerged at the same depth in the liquid under investigation. These bodies have the same true weight and the same aerodynamic resistance, but different volumes V_1 and V_2 (V_1 being > V_2) and corresponding specific weights γ_1 and γ_2, which sufficiently exceed the greatest value of the specific weight being measured.* In this case $\gamma_1 V_1 = \gamma_2 V_2$ and hence

$$\gamma_2/\gamma_1 = V_1/V_2. \quad (1)$$

The bodies must be of such shape that the aerohydrodynamic forces acting on them in the ascending flow are equal at any operative rate of flow. The sizes of the bodies submerged in the suspension must be large compared with the sizes of the suspended particles.

Each submerged body will be acted on by an upward thrust equal to the weight of the medium in a volume equal to that of the body and, in addition, in the case of an ascending vertical flow, by an aerohydrodynamic force f. Thus, in the general case, the first (larger volume) and second (smaller volume) bodies will be acted on respectively by the downward directed resultant forces:

$$P_1 = \gamma_1 V_1 - \gamma_c V_1 - f_1 = V_1 (\gamma_1 - \gamma_c) - f_1 \quad (2)$$
$$P_2 = \gamma_2 V_2 - \gamma_c V_2 - f_2 = V_2 (\gamma_2 - \gamma_c) - f_2. \quad (3)$$

given that

$$f_1 = \zeta_1 F_1 \gamma v^2/2g. \quad (4)$$
$$f_2 = \zeta_2 F_2 \gamma v^2/2g. \quad (5)$$

where

γ is the specific weight of the flowing medium;
v is the rate of the ascending flow;

F_1 and F_2 are the areas of the midship sections of the first and second bodies;

ζ_1 and ζ_2 are the resistance coefficients of the first and second bodies; these depend on the Reynolds number.

The resultant force $P = P_2 - P_1$, measured by the balance, is equal to

$$P = \gamma_c (V_1 - V_2) + f_1 - f_2. \quad (6)$$

When the shapes and sizes of the bodies are such that $f_1 = f_2$, i.e., when the following condition holds:

$$\zeta_1 F_1 \frac{\gamma v^2}{2g} = \zeta_2 F_2 \frac{\gamma v^2}{2g}, \quad (7)$$

The balance will measure a force P equivalent to the weight of a volume of the medium equal to the difference in volumes of the submerged bodies:

$$P = \gamma_c (V_1 - V_2). \quad (8)^{**}$$

*If the density of the medium is constant with respect to height, we can, where necessary, submerge the first and second bodies at different depths, thus ensuring the required balance. The bodies must be submerged at points with an equal rate of flow (usually points symmetrical with respect to the vertical axis of the chamber), and in the case of measurement of the mean density of the suspensions – at a distance from the axis corresponding to the mean rate of flow.

**Hence also: $P = \gamma_c V_1 (1 - V_2/V_1) = \gamma_c V_2 (V_1/V_2 - 1)$.

and hence the specific weight of the suspension is determined by the relation

$$\gamma_c = \frac{P}{V_1 - V_2}. \tag{9}$$

In the absence of flow, (8) and (9) are valid irrespective of any conditions.

Thus, according to (9) the balance reading will give the specific weight and bulk density ($\rho_c = \gamma_c / g$) of the suspension or, in general, of any medium in which the indicator-bodies are submerged.

The scale of the instrument is graduated directly in units of bulk density or specific weight (for any difference of volumes of the submerged bodies); in this case the instrument directly registers the density or specific weight of the medium under investigation.

The submerged bodies, as already indicated, must have the same true weights. If the weights of the bodies are made equal by weighing in air without a correction being introduced for the weight of the volumes of air displaced, then the appropriate correction must be introduced into the measured value γ'_c: the specific weight of the air γ_a is added to the value γ'_c. In fact in this case $\gamma_1 V_1 - \gamma_a V_1 = \gamma_2 V_2 - \gamma_a V_2$; with $f_1 = f_2$ the force P' measured by the balance is equal to

$$\begin{aligned} P' &= (\gamma_2 V_2 - \gamma_c V_2) - (\gamma_1 V_1 - \gamma_c V_1) = \gamma_2 V_2 - \gamma_1 V_1 + \\ &+ \gamma_c (V_1 - V_2) = \gamma_c (V_1 - V_2) - \gamma_a (V_1 - V_2) = \\ &= (\gamma_c - \gamma_a)(V_1 - V_2), \end{aligned} \tag{10}$$

from which

$$\gamma_c = \frac{P'}{V_1 - V_2} + \gamma_a = \gamma'_c + \gamma_a. \tag{11}$$

when the value γ_a is negligibly small in comparison with γ_c, the correction for it is of no practical significance.

If the difference in volumes of the first and second body (which have equal true weights) $V_1 - V_2 = V_k$ is equal to 1, then from (8) $P = \gamma_c$, i.e., the force measured by the balance is equal to the specific weight of the suspension.

Expressing P in grams, we will have in the case where $V_k = 1\ cm^3$, $\gamma_c = P\ g/cm^3$ while with $V_k \neq 1$ cm, we will have $\gamma_c = P/V_k\ g/cm^3$, the scale of the instrument as already stated, being graduated directly for specific weight or for density.

The shapes of the bodies must be such that condition (7) is satisfied, i.e., the relation between the dimensions must be such that $\zeta_1 F_1 = \zeta_2 F_2$. We can select various combinations of shapes of first and second body for which this condition is met with sufficient accuracy.

In the case where the shapes are the same (similar) the resistance coefficients of both bodies are the same but the midship sections are different. In the case of equal midship sections the resistance coefficients differ to some extent; by a suitable choice of shapes, however, this difference can be made very slight. The necessary results will be obtained if both bodies have equal midship sections and shapes for which the flow conditions are approximately the same, so that the difference between the aerohydrodynamic forces acting on the first and second body will be neglibly small. In this case the bodies must be hung so that the surfaces with the same profile face downward – to meet the ascending flow.

We take two bodies of equal midship section, the lower portions of which, lying below the midship section and facing into the flow, have equal shape and size, while the upper portions have similar shape but different heights; we must choose such shapes that the resistance coefficients ζ_1 and ζ_2 (and, hence, forces f_1, f_2 and their difference) are as small as possible. The resistance coefficients of such bodies are close to one another. In fact, since the midship section of both bodies and the shape and size of their lower portions are the same, the dynamic pressure on each of the bodies is the same. The friction on the lower parts of the first and second body is also the same, though it differs somewhat over the whole surface, but with the low rates of ascending flow normally used for obtaining suspensions this difference is insignificant. In laminary flow there is no break-away in the stream and no eddy formation: in the case of turbulent flow the difference in the break-away

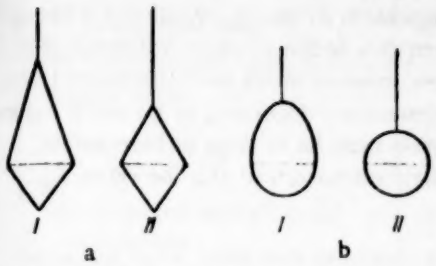

Fig. 1. Shapes of indicator-bodies ($V_1/V_2 = 1.435$).

effects and eddy formation behind the midship sections of first and second bodies which have suitably chosen shapes is insignificant when the Reynolds number is low, and the effect of this difference is of no importance in comparison with the values being measured.

Thus, for such bodies the difference between the coefficients ζ_1 and ζ_2, and also the difference between the forces f_1 and f_2 (in comparison with the value $\gamma_c V_k$) will be negligibly small.

We must also remember that in the case of shapes which have a horizontal or insufficiently inclined upper surface there may be an accumulation of particles of the solid phase on it; hence such shapes are unsuitable for measurements in suspensions. On smooth surfaces with a sufficiently large angle of inclination (more than 45°) the particles do not stick.

A good shape for the indicator-bodies, and one that meets the above-mentioned requirements and is simple to make is a double cone consisting of two right circular cones (of equal base) joined at their bases and with the apices pointing in opposite directions. In this case the bodies consist of two double cones with equal midship section diameters and with equal lower cones, the apices of which point downward (Fig. 1a).

Other streamlined shapes may be used – for instance, ones having their lower portions in the form of equal semi-ellipsoids or hemispheres, while the upper portions are right circular cones of equal bases but different heights.

In the case of pure flow another good shape is the streamlined ellipsoidal form, where each body consists of a combination of two semiellipsoids with equal short axes and with the long ends facing in opposite directions, the lower semiellipsoids being equal in the first and second body, but the upper ones having long semiaxes of different length. A particular case of such shapes is a pair of bodies, where the smaller is a sphere, and the larger a hemisphere (lower) semiellipsoid (upper) of the same diameter, the lower parts of the two bodies being identical hemispheres (Fig. 1b). However, the construction of bodies of ellipsoidal form, and in particular of the hemisphere semiellipsoid presents considerable difficulty.

In the case of a stationary medium, where $f_1 = f_2 = 0$ and the shape of the bodies has no bearing, we can make both bodies in the shape of spheres with diameter ratio $d_1/d_2 = \sqrt{V_1/V_2}$ or in the form of right circular cones with equal bases or similar shapes with the apices pointing upwards; an instrument with such bodies, however, is unsuitable in the case of an ascending flow and, in particular, does not permit measurements in suspensions produced by a current or in boiling layers.

A greater difference in the volumes of the bodies means higher sensitivity of the instrument and greater accuracy in measurement, since for each values of γ_c there corresponds a greater weight $P = \gamma_c V_k$. This is particularly important in the case of small γ_c, where a correspondingly greater difference of volumes V_k is essential in order that the value $\gamma_c V_k$ should be large enough; for larger values of γ_c we can choose a smaller V_k. On the other hand, greater values of V_k, being associated with more or less large volumes of submerged bodies (both or one of them), limit the possibility of point measurements of γ_c – particularly with respect to height. Small values of V_k, obtained by making V_1 and V_2 small, permit point measurements, but do not always provide sufficient accuracy (especially with small γ_c). In the case where V_k is too small, measurements may even be impossible when strong eddy movements are present, since the action of the insufficiently large force $\gamma_c V_k$ will be masked by the vibrations of the bodies and cannot be registered.

In choosing the volumes of the bodies we must bear in mind, besides the conditions mentioned in respect of the effect of the value V_k, that it is desirable to choose the ratio V_1/V_2 as close as possible to 1, in which case the volumes must be sufficiently large for each V_k, and that a reduction in volumes increases the sensitivity to movements of the medium; in addition, the effect of errors made in the sizes in constructing the bodies becomes greater; moreover, we must consider the volume of the medium in which the measurements are being made.

Thus the best values of V_1, V_2 and V_k must be determined in relation to various conditions from a consideration of 1) the range of values of the specific weight being measured, so that $\gamma_c V_k$ should have a large enough value over the whole range of γ_c; 2) the speed of the ascending flow and the concomitant state of the

medium, so that the bodies should have a sufficiently large weight $\gamma_1 V_1 = \gamma_2 V_2$, thus ensuring their stability, and the value $\gamma_c V_k$ should permit measurement with the required degree of accuracy; 3) that V_1/V_2 should differ as little as possible from 1; 4) the necessity for point measurements, which requires bodies of small volume; 5) the volume in which the measurements are made. In general we should choose volumes which are sufficiently large, and only when $\underline{v}$ is small and γ_c is large in the case where point measurements are necessary, or for small volumes of medium, should they be small, but the difference in volumes of the bodies must be as large as permissible. If strong eddy movements are likely the masses of the bodies and hence their volumes, and also the value V_k, must be as large as possible.

The linear dimensions of the bodies of any shape or volume must be chosen so that there is the best combination of low resistance coefficient (and with the condition $\zeta_1 \approx \zeta_2$ satisfied), concentration of volume, large angle of inclination of upper surface, sufficiently small height and simplicity of construction. Sample linear dimensions of bodies of several shapes, determined from a consideration of these conditions for different volumes and volume differences, are given in the table.

The specific weights of the first and second body must satisfy (1), i.e., $\gamma_2 = \gamma_1 V_1/V_2$.

The absolute values of the specific weight of the bodies must be chosen large enough to ensure that each of them will be much greater than the greatest sum of the specific weight of the suspension and aerohydrodynamic force acting upwards per unit volume of the body. This is dictated by the fact that in an ascending flow, when the suspension is in a more or less turbulent state and the bodies submerged in it are subject to the action of its eddy motions, the weight must be sufficiently great to ensure the stability of each body and at the same time much greater than the total force acting on it from below. If there is a possibility of strong eddy motions the specific weight of the bodies must be chosen as large as possible.

On the other hand, where there is no need (in a stationary medium), the specific weight of the bodies must not be made too great, since the smaller the weight of bodies of given volumes, the greater the accuracy of measurement which can be obtained.* For instance, in the case of a stationary medium, if we are required to increase the sensitivity of the instrument we can take the specific weight of the first body a little greater than the maximal specific weight of the suspension, and the specific weight of the second body from (1).

It is most convenient to construct hollow bodies and to fill them with a heavy substance (for instance, tungsten, lead or mercury) until the required specific weight is obtained. In this case we can make one of the bodies hollow (it is more convenient to do so with the larger, and to make the smaller body entirely of material of appropriate specific weight), or both. It is impossible in practice, apart from isolated cases, to choose suitable materials of the required specific weights for the entire construction of the two bodies. The mass of hollow bodies may be varied within certain limits by changing the amount of heavy substance they contain.

For different conditions, we can employ, besides bodies of variable mass, interchangeable bodies (particularly, interchangeable pairs of bodies) of different size and mass, with the instrument scale calibrated accordingly.

The two bodies are suspended on fine wires on opposite arms of a sensitive balance with a sufficiently long scale and scale divisions corresponding to the required accuracy of measurement. The wires must be attached without upsetting the weight balance and ratio of the volumes (for instance, inside the bodies).

Various designs of balance may be employed for the measurements. Simple equal-arm beam balances possessing a beam and long pointer of sufficiently small mass, corresponding to the required sensitivity (Fig. 2), are convenient. An increase in the sensitivity of such balances is achieved by the use of a light beam and pointer but this, of course, makes them very sensitive to vibrations of the suspended bodies. The pointer may be furnished with a sliding weight and the beam with different points of suspension for the bodies, thus permitting a regulation of the sensitivity of the instrument. It is also possible to make several interchangeable beams and pointers of different masses for use in different conditions. The section of the beam must have a profile of streamlined form tapering gradually to a sharp point at the top (so that when the instrument is placed in the working volume, or above, the suspension ejected and flying particles cannot settle on the beam).

*When the specific weight of bodies of given volumes is increased the weight of each body increases, while the weight of the displaced volume of suspension is unaltered and the balance measures the same force with a greater weight of body (with a proportional increase of volume of bodies of given specific weight there will be an equal increase in the weight of the body and the weight of the volume of suspension displaced, so that the balance measures a correspondingly greater force).

Shape of bodies	$V_к$, cm³	V_1, cm³	V_2, cm³	d_1, mm	d_2, mm	$h_{к1}$, mm	$h_{в1}$, mm	h_1, mm	$h_{к2}$, mm	$h_{в2}$, mm	h_2, mm
Double cones	1.0	2.0	1.0	15.0	15.0	9.0	24.96	33.96	9.00	7.98	16.98
	1.0	3.3	2.3	18.0	18.0	12.0	26.90	38.90	12.00	15.12	27.12
	5.0	15.0	10.0	32.0	32.0	18.50	37.45	55.95	18.50	18.80	37.30
	8.0	25.0	17.0	36.0	36.0	20.00	53.70	73.70	20.00	30.10	50.10
	10.0	25.0	15.0	37.0	37.0	21.00	48.75	69.75	21.00	20.85	41.85
	25.0	75.0	50.0	56.0	56.0	30.50	60.85	91.35	30.50	30.40	60.90
Hemisphere/ semiellipsoid and sphere	1.0	2.0	1.0	12.4	12.4	6.20	18.60	24.80	6.20	6.20	12.40
	1.0	3.3	2.3	16.37	16.37	8.19	15.66	23.85	8.19	8.19	16.37
Spheres	0.1	0.2	0.1	7.26	5.76	3.63	3.63	7.26	2.88	2.88	5.76
	0.1	1.1	1.0	12.8	12.4	6.40	6.40	12.80	6.20	6.20	12.40
	1.0	2.0	1.0	15.63	12.4	7.81	7.81	15.63	6.20	6.20	12.40
	1.0	3.3	2.3	18.46	16.37	9.23	9.23	18.46	8.19	8.19	16.37
Cones (right circular)	1.0	2.0	1.0	16.0	16.0	–	29.84	29.84	–	14.92	14.92
	1.0	2.0	1.0	16.0	12.7	–	29.84	29.84	–	23.69	23.69
	1.0	3.3	2.3	21.12	21.12	–	28.26	28.26	–	19.69	19.69
	1.0	3.3	2.3	21.12	18.45	–	28.26	28.26	–	25.81	25.81

Note: d_1 and d_2 are the diameters of the middle section; h_{H1} and h_{H2} are the heights of lower portions; h_{B1} and h_{B2} are the heights of upper portions; h_1 and h_2 are the total heights of first and second bodies.

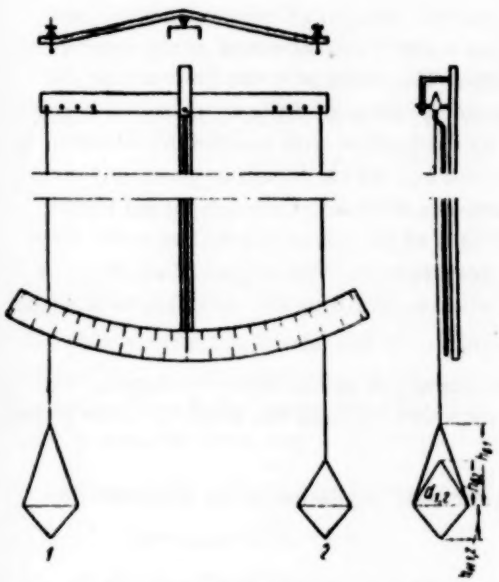

Fig. 2. Arrangement of instrument for measuring density and specific weight of aerosuspensions (boiling and suspended layers) and other media. The sizes of the beam and pointer depend on the given size of the least working volume and the degree of sensitivity; $V_1 = 25$ cm³; $V_2 = 17$ cm³; $d_1 = d_2 = 36$ mm; $h_{H1} = h_{H2} = 20$ mm; $h_{B1} = 53.7$ mm; $h_{B2} = 30.1$ mm; above-case of beam with mounting and suspension on knife-edges.

The beam of the balance is mounted on a knife-edge on the bearing or on a horizontal rod perpendicular to it and round which it can rotate freely, or it is suspended.

The beam and pointer are made from metal or of other material of a density which depends on the required sensitivity of the instrument. The pointer can be made of a lighter material (for example, the beam from copper or brass, the pointer from duralumin). Glass can be employed in balances intended for laboratory measurements in stationary media.

Depending on the construction of the chamber in which the measurements are made, the balance (measuring device) is mounted outside or inside the chamber. When the balance is mounted outside the chamber (on the top or on a special support) the wires on which the submerged bodies hang pass through slots in the top of the chamber and the balance is enclosed in an airtight cover placed over it and covering the slots; the cover is made from plexiglas or other suitable transparent material, or with windows of these materials for illumination and observation of the scale.* In the case of mounting inside the chamber, the whole instrument with the weights is inserted into it on a rod passing through a packing gland in the top or, where necessary, on a rod passing through a packing gland in the wall; when required, an airtight hatch can be made in the wall with a cover furnished with a packing gland. The balance can be placed inside the chamber if the latter is constructed of transparent material (plexiglas , for instance) or has a window of such material. Where other measuring devices are used instead of a beam balance for registering the measurements, various methods of transmission are feasible.

*When the apparatus does not require to be airtight (for instance, in the case of hydrosuspensions), the cover is not put on.

The depth of submersion of the bodies can easily be altered by a vertical shift of the rod to which the instrument is attached.

We give several sample combinations of sizes and weights of indicator-bodies (shape of bodies – double cones) for the most difficult measurements in aerosuspensions produced by an ascending flow, including boiling layers.

For aerosuspensions with strong vortex motions the most suitable bodies for most practical cases are a pair in which the larger has a volume $V_1 = 25$ cm^3, and the smaller $V_2 = 17$ cm^3, so that $V_k = 8$ cm^3. In several cases smaller volumes are adequate: $V_1 = 15$ cm^3 and $V_2 = 10$ cm^3, $V_k = 5$ cm^3. The best linear dimensions for such double cones are given in the table. It is advisable to make both bodies hollow (of copper, bronze, brass, steel etc)* filled with tungsten (or mercury): the small one should be completely filled and the larger until the required weight is obtained.** When the mean specific weight of the smaller body is $\gamma_2 = 14$ g/cm^3 the mean specific weight of the larger body in the case of the first set of volumes must be $\gamma_1 = 9.52$ g/cm^3, for the second set $\gamma_1 = 9.33$ g/cm^3. The true weight of each body is equal in the first case to 238 g, and in the second case to 140 g. Sometimes it is more convenient to make the smaller body entirely of lead or of lead with a strong (copper, bronze, brass) coating, and the larger body hollow, filled to the required level with lead; then with $\gamma_2 = 11.34$ g/cm^3 the true weight of each body will be 192.78 g or 113.4 g, respectively. For greater working volumes of suspension, where it is necessary to increase the stability of the system, we may choose larger volumes of bodies and a higher V_k; for instance, $V_1 = 75$ cm^3 and $V_2 = 50$ cm^3, V_k being 25 cm^3 and the true weight of each body with $\gamma_2 = 14$ g/cm^3 will be equal to 700 g.

The arrangement of the instrument for measuring the density (specific weight) of aerosuspensions, and other media is shown in Fig. 2.*** When suitably calibrated it can give a direct measurement of the density or specific weight of the medium under investigation and of their changes. The instrument can be made for different ranges of measurement (for instance, by the use of interchangeable pointers of different mass and appropriately graduated scales). The instrument can easily be calibrated by comparison with standard hydrometers in liquids of different density (with no ascending flow). The instrument can also be calibrated in grams and a conversion made to a scale of densities in g/cm^3 from the known difference in volumes of the submerged bodies. For checking we can determine experimentally the resistance coefficients of the submerged bodies in the range of values of the Reynolds number corresponding to the conditions of measurement. The degree of accuracy of the instrument depends on the error of the balance readings and the accuracy in filling the indicator-bodies (the measurement error also depends on the state of the medium).

With a suitable choice of shapes, dimensions and masses of the submerged bodies, and of measuring devices, the described method (by allowing, in particular, an increase in the mass and, hence, of the stability of the bodies) is applicable in different conditions.

This method of density measurement also makes possible the automatic regulation of the concentration and density of suspensions.

SUMMARY

1. A method has been devised for the direct and continuous measurement of density and specific weight of suspensions and in general of suspensions, including boiling layers of small particles, as well as of liquids and gases, in an ascending flow, the speed of which may be variable (applicable also in the absence of an ascending flow).

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*For measurements in suspensions formed by magnetic particles, the bodies and all other submerged parts of the instrument must be made of weakly diamagnetic materials – copper, for instance. Where very large temperature variations are possible both bodies must be made of the same materials and where necessary we must allow for the thermal change in their volumes.

**When mercury is used for filling, the inside must be lined with a resistant, protective layer; the excess free volume should be filled with suitable material – paraffin, wax etc – to prevent the mercury being shaken; a certain amount of the cavity should be left unfilled to allow for the greatest possible thermal expansion of the mercury.

***In an instrument intended for measurement in the dressing of coal and mineral ores, the whole submerged part must be protected by a strong coarse-meshed grid which does not hinder the movement of the suspension.

2. The essence of the method is the submersion in the investigated medium of two specially shaped bodies suspended on opposite arms of the balance (or some other measuring device), these bodies having the same true weight and equal aerohydrodynamic resistance, but different volumes. In this case the balance measures the weight of a volume of medium equal to the difference in volumes of the submerged bodies, and when suitably calibrated directly registers the specific weight or bulk density of the medium (the scale of the instrument is graduated in units of specific weight or density for any difference in volume of the bodies).

3. The bodies may have various special shapes which ensure the equality of their aerohydrodynamic resistances. The employment of bodies of shapes which satisfy the equal resistance condition is essential, since this makes it possible to conduct measurements in an ascending flow.

4. We determined the shapes of bodies of different volumes, which satisfied the requirement of equal resistance in practical conditions of measurement, and which ensured the equality of the aerohydrodynamic forces acting on these bodies in an ascending flow at any practical rate. Double cones are most suitable in practice.

5. The difference in volumes, the volumes themselves, and the masses of the bodies may be altered to suit the purpose of the instrument and the corresponding measurement conditions.

In the case of strong eddy motions we must use bodies of large mass, which ensures their stability, and the difference in volumes must also be sufficiently large.

ON THE QUESTION OF WEIGHT DETERMINATION BY THE METHOD OF β-RAY ABSORPTION (ERROR CURVES)

V. S. Merkulov

The radioactive method of determining weight (thickness, density), based on the phenomenon of β-ray absorption, is widely employed in measurement techniques, instrument construction and industry. According to this method the object under inspection (the medium) is interposed between a radiation source and a detector, and the required parameter is determined from the degree of absorption of the radiation.

Among the advantages of this method we must include

1) contactless inspection;

2) the possibility of rapid, continuous and automatic inspection and control of industrial processes.

β-ray absorption is the basic principle of a whole series of thickness, density and weight gages of varied design, and this method is used in a large number of cases. For instance, pure β-emitters are used with success for contactless measurement and automatic control of the thickness of rolled metal, plastics, rubber, leather, coated materials, paper, cardboard, cellophane, abrasives, cinefilm, adhesive tape, inked ribbons etc.

The majority of radioisotopes decay with the emission of β-particles, but only some of them are pure β-emitters. Pure β-emitters which are employed in practice cover a wide range of energies from tens of kev (Ni^{63}) to several Mev (Y^{90}). Certain β-emitters are exceptionally valuable and convenient radiation sources owing to their favorable combination of high emission energy and long half-life.

In the table we give the main characteristics of the most important artificial radioactive isotopes with a simple β-spectrum, and which are of interest as β-ray sources and are employed with success for measurement of weight (thickness, density).

The question of accuracy in measurement is of decisive significance, and, hence, we describe below a method of weight measurement and give families of curves of statistical errors in determining the weight of a substance by the β-ray absorption method for the case of the pure β-emitters most extensively used in measurement technique.

β-isotope (symbol)	Half-life	Maximum energy of β-emission E_β, Mev	Maximum range of β-particles R_β, mg/cm²	Half-thickness $l_{\frac{1}{2}}$, mg/cm²	Approximate value of mass absorption coefficient μ_0, g/cm²	Permissible range of weight measurement, mg/cm²	Weight corresponding to the minimum error, mg/cm²
Sr^{90}	53 days	1.463	690	97	7.1	20–400	281
Sr^{90}–$_{39}$	19.9 yrs	0.610	210	24.4	28.4	5–100	70
Y^{90} (Daughter product)	61 hrs	2.180	1100	150	4.6	30–650	435
P^{32}	14.3 days	1.701	800	115	6	20–450	333
Pr^{143}	13.7 .	0.932	370	48	14.4	15–200	138.8
Tl^{204}	3.5 yrs	0.765	280	35	19.8	10–150	101
Ca^{45}	152 days	0.250	57	5.5	126	1–20	15.8
Pm^{147}	2.6 yrs	0.223	51	4.5	132	1–20	15.1
S^{35}	87.1 days	0.169	32	3	231	0.5–10	8.6
C^{14}	5568 yrs	0.155	34	2.6	266	0.5–10	7.5

Note: The mass absorption coefficient is obtained from the formula $\mu_0 = 0.693/l_{\frac{1}{2}}$, where $l_{\frac{1}{2}}$ is expressed in grams per 1 cm². The values of $l_{\frac{1}{2}}$ for most of the isotopes are taken from N. G. Gusev's book "Handbook on Radioactive Emissions and Protection," Medgiz, 1956.

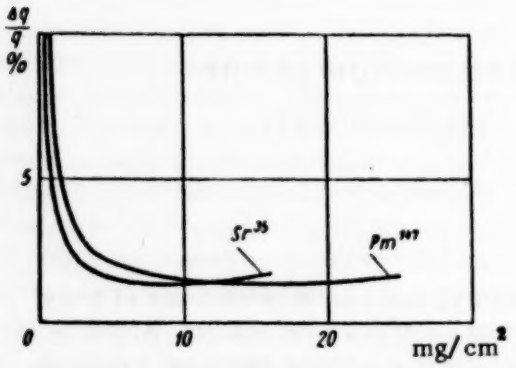

Fig. 1. The error $\Delta q/q$, due to the statistical error in registering the radiation, as a function of the weight q for the β-emitters S^{35} and Pm^{147} ($I_0 = 10^4$ counts/min).

As we know, the absorption of a β-ray flux passing through a layer of matter is subject in the first approximation to an exponential law:

$$I = I_0 e^{-\mu l}, \qquad (1)$$

where I is the β-ray flux incident on the detector after passing through a layer of the absorber of thickness l;

I_0 is the initial β-ray flux incident on the detector when the absorber is absent;

μ is the linear absorption coefficient (cm^{-1}).

The absorption of β-rays depends mainly on the number of electrons in unit volume of the absorber, and μ will be proportional to the product $(Z/A)\rho$ where ρ is the density of the absorbing medium, Z is the atomic number and A the atomic weight of the material of the absorber. On progression from light elements to heavy elements the ratio Z/A changes slightly (slowly diminishes).

Hence, we may assume that μ_0 is approximately proportional to ρ. Hence the mass absorption coefficient μ_0, defined as $\mu_0 = \mu/\rho$, will be approximately constant for different substances, i.e., the attenuating power of unit mass will be practically independent of the nature of the absorber.* Thus, the degree of attenuation of the β-ray flux is determined predominantly by the weight of matter in g/cm² or mg/cm² (product ρl) in the path of the radiation.

We denote the product ρl by $\underline{q}$. Then (1) will take the following form:

$$I = I_0 e^{-\mu_0 q}. \qquad (2)$$

Let us estimate the accuracy in determining the weight of a substance in the case of measurement by the method of β-ray absorption. Differentiating (2) we obtain a relation connecting the mean-square relative statistical error in the registration of the β-ray flux $\Delta I/I$ with the mean-square relative error in determining the

*An exception is hydrogen (H^1), which has twice as many electrons per 1 g as any other light element.

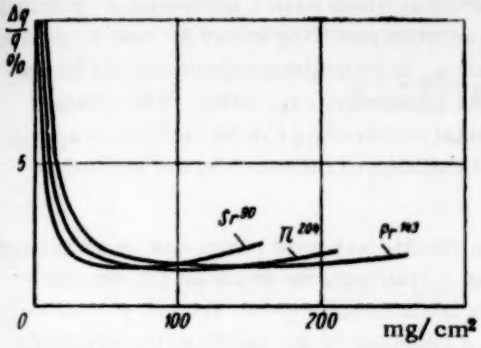

Fig. 2. Error $\Delta q/q$, due to the statistical error in registration of the radiation, as a function of the weight q for β-emitters Tl^{204}, Sr^{90}, Pr^{143} ($I_0 = 10^4$ counts / min).

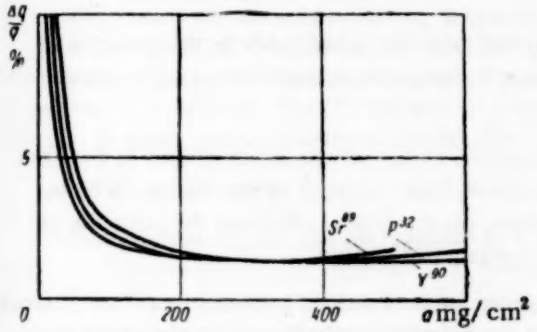

Fig. 3. Error $\Delta q/q$, due to the statistical error in registering the radiation, as a function of weight q for β-emitters Sr^{89}, P^{32} and Y^{90} ($I_0 = 10^4$ counts/ min).

weight $\Delta q / q$:

$$\frac{\Delta q}{q} = -\frac{1}{\mu_0 q} \cdot \frac{\Delta I}{I}. \qquad (3)$$

The phenomenon of radioactive decay has a statistical nature, and the relative error in registering the radiation flux $\Delta I / I$ (with 100% efficiency in registration and time of measurement 1 min), is determined from the formula

$$\frac{\Delta I}{I} = \frac{1}{\sqrt{I}}. \qquad (4)$$

Substituting the value $\Delta I / I$ in (3) we obtain a final expression for the mean square relative error in determining the weight, this error being due to the statistical error in registering the radiation (we neglect the mean-square error due to imperfection of the apparatus).

$$\frac{\Delta q}{q} = \frac{1}{\mu_0 q} \cdot \frac{1}{\sqrt{I}} = \frac{e^{\frac{1}{2}\mu_0 q}}{\mu_0 q \sqrt{I_0}}. \qquad (5)$$

According to (5), the relative error in the weight determination $\Delta q/q$ with I_0 constant will be minimal when $\mu_0 = 2/q$ (optimal condition), and, hence, by selecting the radiation energy we can ensure a preset accuracy of measurement over a wide range of weight variation.

For a given range of weight variation the radioactive isotope should be chosen from a consideration of this optimal condition. If this condition cannot be met exactly (this may happen in using a particular model of weight gage or where a limited number of pure β-emitters is available) we must work in the region of variation of q for a given μ_0, so as to come as near as possible to the optimal condition.

The values of the relative errors in determining weight by the method of β-ray absorption are calculated from (5). Error curves are obtained for all the β-emitters given in the table, for a radiation flux $I_0 = 10^4$ counts/ min.*

In the case of using radiation fluxes of different intensity I_0, and with the values of μ_0 and q unaltered, the values of the relative errors given by the curves are multiplied by a factor $\sqrt{10^4/I_0}$. The families of error curves for different values of μ_0 (for different β-emitters) are shown in Figs. 1-3, where the value $\Delta q/q$ is plotted as a function of the weight q. These curves enable us to make a rational choice of isotope as a β-ray source in tackling a particular problem of weight determination with a required degree of accuracy.

On Fig. 4 we give similar error curves for density measurement by the method of radiation absorption for the β-emitters S^{35}, Ca^{45}, Tl^{204}, Sr^{90} and Pr^{143}, calculated for the case of a layer of air of thickness 100 mm. The ratio ρ / ρ_0 is plotted on the x-axis, where ρ_0 is the density of air under normal conditions; the relative error is plotted as a percentage on the y-axis (semilogarithmic scale).

The use of the equation $q = 1/\mu_0 \ln I_0/I$ for calculating the weight by the method of radiation absorption assumes the presence of β-emitters with a simple spectrum. In practice we have sometimes to deal

*Error curves for C^{14} and Ca^{45} are not given on the graphs, since they lie close to the error curves for S^{35} and Pm^{147}, respectively. For $Sr^{90} \rightarrow Y^{90}$ the error curves are calculated for each isotope.

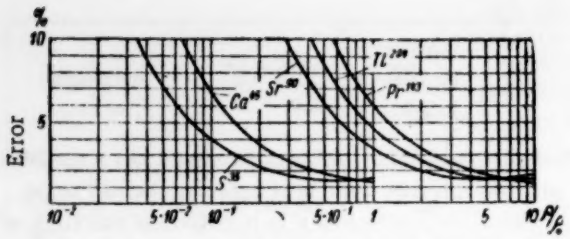

Fig. 4. The error $\Delta\rho/\rho$, due to the statistical error in registering the radiation, as a function of the density of air, for the β-emitters S^{35}, Ca^{45}, Tl^{204}, Sr^{90} and Pr^{143}, with width of tube 100 mm ($I_0 = 10^4$ counts/min).

with β-emitters which have a compound β-spectrum, and with emitters providing mixed β- and γ-radiation.* In this case μ_0 is determined experimentally by conducting the appropriate calibration. The obtained experimental values of μ_0 can be used for an approximate calculation of the errors by the method indicated.

In a similar way error curves can be calculated for γ- and x-radiation, for which an exponential absorption law also holds good. For soft γ- and x-emission, μ_0 depends on the nature of the absorber.

This method of calculation of error curves is valid in the case where the absorption obeys an exponential law, and, hence, in working with particular models of β-radiation weight gages we must calibrate the apparatus, thus enabling us to check the form of the absorption curve. As we know, in using thick β-sources self-absorption occurs, which leads to distortion of the spectrum. In the case where very thin β-sources are used reflection of β-particles from the material of the substrate is possible. Clipping of the β-spectrum and distortion of its form are unavoidable in the presence of foils or any kind of films used for protecting the active layer during its preparation, and also owing to the absorption of radiation by the walls of the detector.

Besides this, it has been found that the curvature of the absorption curve may be much greater in the case where tubular attachments (louvers) for isolating narrow beams of β-rays are mounted on the source. We also know that β-rays interact with matter to generate x-rays. Of course, all the factors affecting the radiation absorption can be taken into account by simply carrying out an appropriate calibration.

The inspection of sheet materials requires that the object under inspection should remain in a fixed position in the space between the radiation source and detector. Owing to the scattering of radiation by the absorber the intensity of the registered emission is somewhat greater in the case where the absorber is placed closer to the detector. In conducting measurements close to a wall we must take account of the possible change of radiation intensity due to reflection of β-particles from the wall surface.

* The sources which emit mixed β- and γ-radiation and which are used in instruments include $Ce^{144} \rightarrow Pr^{144}$ and $Ru^{106} \rightarrow Rh^{106}$, which have in their emission spectra an extremely hard β-emission with E_β = 2.97 and 3.5 Mev, respectively. Their application permits an extension of the range of weight measurement to 1000 mg/cm^2 for $Ce^{144} \rightarrow Pr^{144}$ and up to 1200 mg/cm^2 for $Ru^{106} \rightarrow Rh^{106}$. The half-life of Ce^{144} is 282 days, and of Ru^{106} is 1 year.

ELECTRICAL MEASUREMENTS

ELEMENTS OF THE THEORY AND CALCULATION OF BRIDGE CIRCUITS

M. I. Levin

In bridge calculations, the most important characteristics are the sensitivity of the circuit (with respect to current, voltage, or power) and the dependence of the current in (or voltage across) the diagonals of the bridge on a change of the impedance of the arms.

The solution of these and similar problems by the classical methods of linear circuit analysis does not offer any difficulty in principle; however, it is usually associated with cumbersome calculations whose significance is not easily visualized. But if a number of properties which are common to all bridges are taken into account, then, as is shown below by some examples, the calculation can be considerably simplified.

Let us introduce the following definitions and notation.

Every bridge circuit can be regarded as a six-pole network with three pairs of terminals SS, GG, and UU (Fig. 1). The branch S with impedance Z_s is connected to the terminals SS. The emf of the source is in this branch, and it is the input diagonal of the bridge. The branch G with impedance Z_g, connected to the terminals GG, is the galvanometer diagonal; the branch U with the impedance Z_u which is being measured (or which is varying) is connected to the terminals UU. This branch is conventionally called the unknown branch.

The ratio of the emf introduced into any branch of the circuit to the current produced in the same branch by this emf is called the input impedance of the circuit with respect to this branch, and is designated by the letter Z with two like indices (Z_{ss}, Z_{gg}, Z_{uu}). The ratio of the voltage applied at the input terminals of the circuit (for example, the terminals SS) to the resulting input current through these terminals is called the input impedance of the circuit with respect to these terminals, and is appropriately designated as Z_{si}, Z_{gi}. The ratio of the emf acting in any branch of the circuit (for example, in the branch G) to the current produced by this emf in another branch (for example, in the branch U), is called the mutual impedance of these branches, or the transfer impedance of branches G and U and is designated by Z_{gu}. As is well known, according to the reciprocity theorem, the transfer impedance of branch G to branch U is, in a linear passive network, equal to the transfer impedance of branch U to branch G, i.e., $Z_{gu} = Z_{ug}$.

Let us also denote by Z_{su_0} and Z_{gu_0} the transfer impedances of branches S, G and U for zero impedance diagonals, i.e., for $Z_s = 0$ and $Z_g = 0$.

The reciprocals of the input and mutual impedances are, respectively, the input and mutual admittances. We shall designate them by the letter Y and the same indices.

In accordance with the adopted definitions, the conditions for balance of any bridge can be written in the form $Z_{sg} = \infty$ or $Y_{sg} = 0$.

It is not difficult to see that a balance Z_{ss} and Z_{su} do not depend on Z_g, the impedance of the diagonal and galvanometer; and that Z_{gg} and Z_{gu} do not depend on Z_s, the impedance of the input diagonal. This fact significantly simplifies the calculation of these impedances in the balanced circuit, since the input and mutual impedances involving one diagonal can be calculated with the second diagonal either open circuited or short circuited. For the simplest designs, we shall find how the values of the impedances Z_{ss}, Z_{su} depend on the impedances of the second diagonals in a balanced circuit. With the adopted notation,

$$Z_{ss} \quad Z_s + Z_{si} = Z_{si} \left(1 + \frac{Z_s}{Z_{si}}\right) = Z_{si} \quad (1 + k_s), \tag{1}$$

where

$$k_s = \frac{Z_s}{Z_{si}},$$

$$Z_{gg} = Z_g + Z_{gi} = Z_{gi}\left(1 + \frac{Z_g}{Z_{gi}}\right) = Z_{gi}\ (1 + k_g), \tag{2}$$

where

$$k_g = \frac{Z_g}{Z_{gi}},$$

k_s and k_g will be called the matching factors of the impedances of the diagonals with the impedances of the circuit.

Moreover, it can be shown that Z_{su} and Z_{su_0}, and also Z_{gu} and Z_{gu_0} are connected by analogous relations. In fact, assuming that in the branch S with impedance Z_s there acts an emf E, producing a current I_{u_0} in the branch U (Fig. 1), we can write, in accordance with the definition of the transfer impedances

$$Z_{su} = \frac{\dot{E}}{I_{u_0}} \text{ and } Z_{su_0} = \frac{\dot{U}_{ss}}{I_{u_0}}, \text{ where } Z_{su} = Z_{su_0}\frac{\dot{E}}{\dot{U}_{ss}}.$$

However,

$$\dot{U}_{ss} = \frac{\dot{E} Z_{si}}{Z + Z_{si}} = \frac{\dot{E}}{1 + k_s}$$

and

$$Z_{su} = Z_{su_0}(1 + k_s). \tag{3}$$

In an analogous manner, one may show that

$$Z_{gu} = Z_{gu_0}(1 + k_g). \tag{4}$$

The parameters introduced – the input and mutual impedances – determine the fundamental measurement properties of a balanced bridge: its current, voltage, or power sensitivity to a change in the impedance Z_u.

Current sensitivity near balance. We denote by Z_{u_0} and I_0 the impedance of the unknown branch and the current in it when the bridge is balanced, and by Z_u and I – these same quantities when the circuit is unbalanced by the introduction of an impedance ΔZ in the branch U. In accordance with the compensation theorem [1], the introduction of the impedance ΔZ is equivalent to the introduction of an emf $E_u = -I\Delta Z$ into the branch U (Fig. 2). Therefore, the change of the current in the branch G upon the introduction of the impedance ΔZ is equal to

$$\Delta I_g = \frac{\dot{E}_u}{Z_{ug}} = -\frac{I\Delta Z}{Z_{ug}},$$

where Z_{ug} is the transfer impedance when the circuit is balanced (independent of ΔZ).

As is well known, the sensitivity of the circuit to a change in the impedance Z_u near the balanced condition, is determined by the relation

$$S_0 = \lim_{\Delta Z \to 0} \frac{\Delta I_g}{\Delta Z}$$

or, substituting the value of ΔI_g,

$$S_0 = \lim \frac{-I\Delta Z}{Z_{ug}\Delta Z},$$

but for $\Delta Z = 0$, $\dot{I} = \dot{I}_0$.

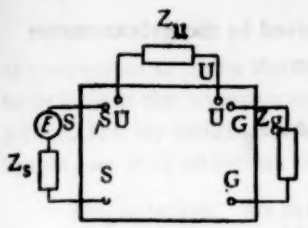

Fig. 1.

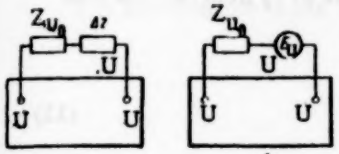

Fig. 2.

Consequently,

$$S_0 = -\frac{I_0}{Z_{ug}} \approx -\frac{I_0}{Z_{ug0}(1+k_g)}. \qquad (5)$$

If the current I_0 is produced by an emf E, acting in the input diagonal, then

$$I_0 = \frac{\dot{E}}{Z_{sg}}$$

and

$$\dot{S}_0 = -\frac{\dot{E}}{Z_{gu}Z_{gu}}. \qquad (6)$$

Substituting into this expression the values of Z_{su} and Z_{gu} from (3) and (4), we obtain

$$\dot{S}_0 = \frac{-\dot{E}}{Z_{su_0}\, Z_{gu_0}(1+k_s)\,(1+k_g)}. \qquad (7)$$

This expression gives the dependence of the current sensitivity of the bridge on the impedances of its diagonals, for the most general case.

S_0 may also be expressed through the current I_s in the diagonal S. Since $\dot{E} = \dot{I}_s Z_{ss} = \dot{I}_s Z_{si}(1 + k_s)$, then

$$S_0 = -I_n \frac{Z_{si}}{Z_{su0} Z_{gu_0}} \cdot \frac{1}{1+k_g}. \qquad (8)$$

Voltage sensitivity. As is well known [2], near a balance, the current sensitivity S_0 is related to the open-circuit voltage sensitivity T_0 by the relation

$$S_0 = \frac{T_0}{Z_g + Z_{gi}} \approx \frac{T_0}{Z_{gi}(1+k_g)}, \qquad (9)$$

where

$$T_0 = \left(\frac{d\bar{U}_g}{dZ_u}\text{open}\right)_{Z_u = Z_{u0}}$$

or $T_0 = S_0 (1 + k_g) Z_{gi}$.

Substituting the value of S_0 into this expression, we obtain

$$T_0 = -I_0 \frac{Z_{gi}}{Z_{ug0}}, \quad T_0 = -\dot{E} \frac{Z_{gi}}{Z_{su0} Z_{ug0}} \cdot \frac{1}{1+k_s},$$

$$T_0 = -I_u \frac{Z_{si}}{Z_{us_0}} \frac{Z_{gi}}{Z_{ug0}}. \qquad (10)$$

The relations (5-10) determine the sensitivity to the absolute value of the change of the impedance Z_u. In order to obtain the sensitivity to the relative change $\epsilon = \Delta Z / Z_{u0}$, it is sufficient to multiply these expressions by Z_{u0}.

Power sensitivity. Since the current I_g in the galvanometer Z_g is, near a balance, equal to

$$I_g = S_0 \Delta Z,$$

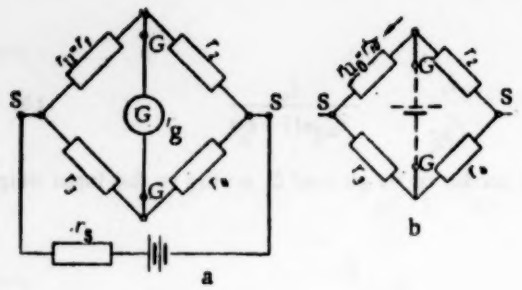

Fig. 3.

then the apparent power received by the galvanometer can be represented in the form

$$P_g = I_g^2 z_g = S_0^2 \Delta z^2 z_g$$

where

$$S_0 = |S_0|,\ \Delta z = |\Delta Z|,\ z_g = |Z_g|.$$

Substituting the value of S_0 from (5), and considering (2), we obtain

$$P_g = \frac{I_0^2 \Delta z^2 |k_g| z_{gi}}{z_{ug0}^2 |1+k_g|^2} = \frac{I_0^2 z_{u0}^2 z_{gi} |k_g|}{z_{ug0}^2 |1+k_g|^2} \epsilon^2 \qquad (11)$$

or

$$P_g = \frac{P_u}{4} \cdot \frac{z_{u0} z_{ug0}}{z_{gi}^2} \cdot \frac{4|k_g|}{|1+k_g|^2} \epsilon^2, \qquad (12)$$

where

$P_u = I_0^2 z_{u0}$ = power dissipated in the unknown branch;

$\epsilon = \Delta z / z_{u0}$ = relative change of the unknown impedance.

It is not difficult to see that for $k_g = 1$, when the galvanometer is said to be matched to the circuit,

$$P_g = \frac{P_u}{4} \cdot \frac{z_{u0} z_{gi}}{z_{ug0}^2}. \qquad (12a)$$

The ratio $P_g/\epsilon^2 = W_{rel}$ is the power sensitivity of the circuit to a relative change of the impedance z_u:

$$W_{rel} = \frac{P_u}{4} \cdot \frac{z_{u0} z_{gi}}{z_{ug0}^2} \cdot \frac{4|k_g|}{|1+k_g|^2}. \qquad (13)$$

If the value $I_0 = E/Z_{su0}|1+k_s|$, is substituted into (11), then we obtain

$$P_g = \frac{E^2}{z_{su0}^2} \cdot \frac{z_{gi}}{z_{ug0}^2} \cdot \frac{|k_g|}{|1+k_g|^2 |1+k_s|^2} \Delta z^2$$

or

$$P_g = P_i \frac{z_{si} z_{gi}}{z_{su0}^2 z_{ug0}^2} \cdot \frac{1}{|1+k_s|} \cdot \frac{|k_g|}{|1+k_g|^2} \Delta z^2, \qquad (14)$$

where $P_i = \frac{E^2}{|Z_s + Z_{si}|} = \frac{E^2}{Z_{si}|1+k_s|}$ = output power of the source.

Examples of the calculation of the sensitivity of bridges. As is clear from the preceding, in order to calculate any of the bridge sensitivies corresponding to any matching factors, it is sufficient to know the two input impedances and the two mutual impedances of the circuit. Since these impedances are calculated for the bridge in the balanced condition and for the diagonal impedances equal to zero or infinity, their calculation does not offer any difficulty even in the case of comparatively cumbersome circuits. It should be noted that in the calculation of the mutual impedances $Z_{su0} = Z_{us0}$, it is convenient to place an emf E' in the branch S and calculate the current produced by E' in the branch U, and not vice versa. Analogously, in order to calculate $Z_{gu0} = Z_{ug0}$, it

is convenient to place the emf in the branch G and calculate the current in the branch U. Consequently, in order to calculate the impedances Z_{sg_0}, Z_{si}, Z_{gi} and Z_{gu_0}, it is sufficient to find the current distribution in the balanced bridge, first by exciting it from the diagonal S, and then by exciting it from the diagonal G. By way of an example, we shall calculate the impedances and sensitivity of two bridges – a single bridge, and a twin T-circuit.

Single bridge. We shall determine the characterisics of a single bridge (Fig. 3a) with resistance $r_{u_0} = r_{10} = 100$ ohms, $r_2 = 200$ ohms, $r_3 = 400$ ohms, $r_4 = 800$ ohms, and $I_{10} = 0.01$ amp: a) when $k_g = 1$; b) when $r_g = 1000$ ohms.

It is not difficult to see that

$$r_{si} = \frac{(r_{10} + r_3)(r_2 + r_4)}{r_{10} + r_2 + r_3 + r_4} = 240 \text{ ohm}$$

$$r_{su_0} = r_{10} + r_2 = 300 \text{ ohm}$$

$$r_{gi} = \frac{(r_1 + r_3)(r_2 + r_4)}{r_1 + r_2 + r_3 + r_4} = 333 \text{ ohm}$$

$$r_{gu_0} = r_{10} + r_3 = 500 \text{ ohm}$$

When $k_g = 1$, in accordance with (5),

$$S_0 = \frac{I_0}{2r_{gu_0}} = \frac{10^{-2}}{2 \cdot 500} = 10^{-5} \text{ amp/ohm}$$

When $r_g = 1000$ ohms, and $k_g = 1000/333 = 3$,

$$S_0 = \frac{10^{-2}}{500\,(1+3)} = 0.5 \cdot 10^{-5} \text{ amp/ohm}$$

Moreover, when $k_g = 1$,

$$W_{rel} = \frac{P_u}{4} \cdot \frac{z_{u_0} z_{gi}}{z_{ug_0}^2} \cdot \frac{4|k_g|}{|1+k_g|^2} = \frac{10^{-4} \cdot 100 \cdot 100 \cdot 333}{500^2} = 1.33 \cdot 10^{-3} \text{ w/l}^2.$$

When $k_g = 3$ ($r_g = 1000$ ohms)

$$\frac{4k_g}{|1+k_g|^2} = 0.75 \quad W_{rel} = 1.33 \cdot 10^{-3} \cdot 0.75 = 1 \cdot 10^{-3} \text{ w/l}^2.$$

Clearly, the sensitivity of the circuit (with respect to current or power) for a given intensity of current in the unknown arm does not depend on r_s.

Twin T-circuit. Let us find the sensitivity of the twin T-circuit pictured on Fig. 4. With $Z_s = 0$ and $Z_g = 0$, it can be represented in the form depicted on Fig. 5a, or in the equivalent form depicted on Fig. 5b. Since, with $Z_g = 0$, the currents in the three-pole circuit B do not depend on the impedances of the three-pole circuit A, and vice versa, the current in the cross connection GG can be found by using the relation

$$I_g = U\,Y_{sga} + U_{sgb}\,Y_{sgb} \qquad (15)$$

where $Y_{sga} = \dfrac{Z_3}{Z_1' Z_2' + Z_2' Z_3' + Z_3' Z_1'}$ is the transfer admittance of branches S and G of the three-pole circuit A (with $Z_s = Z_g = 0$).

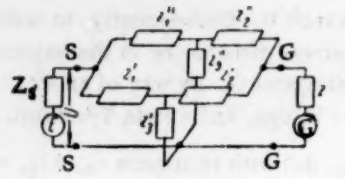

Fig. 4.

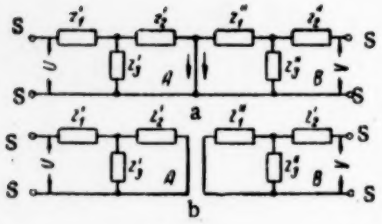

Fig. 5.

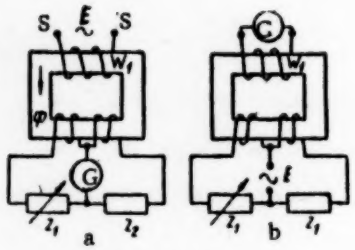

Fig. 6.

$Y_{sgh} = \dfrac{Z_3^*}{Z_1^*Z_2^* + Z_2^*Z_3^* + Z_3^*Z_1^*}$ is the same for the three-pole circuit B (Fig. 5b).

From (15), we obtain the condition for a bridge balance:

$$Y_{sgu} = -Y_{sgh}$$

or, designating $Z_1'Z_2' + Z_2'Z_3' + Z_3'Z_1' = A'$

and $Z_1^*Z_2^* + Z_2^*Z_3^* + Z_3^*Z_1^* = A^*$,

we obtain

$$A'Z_3^* = -A^*Z_3'.$$

The sensitivity of the bridge to a change of any impedance is determined in accordance with (7).

If, for example, the changing impedance is Z_3', then

$$Z_{su_0} = Z_{s3_0} = \frac{A}{Z_2'}, \quad \text{a } Z_{g3_0} = \frac{A'}{Z_1'}.$$

Consequently,

$$S_{03'} = -\frac{\dot{U}\, Z_1'Z_2'}{A'^2 (1 + k_g)(1 + k_s)}.$$

In order to determine the sensitivity with Z_s and Z_g different from zero, it is necessary to calculate the value of k_g and k_s, for which it is necessary to know

$$Y_{si} = \frac{1}{Z_{si}} \quad \text{and} \quad Y_{gi} = \frac{1}{Z_{gi}}.$$

It is not difficult to see that the input admittances of the circuit are equal to the sum of the corresponding admittances of the two three-pole circuits, i.e.,

$$Y_{si} = Y_{si\ A} + Y_{si} \quad \text{and} \quad Y_{gi} = Y_{gi\ A} + Y_{gi}$$

where

$$Y_{si\ A} = \frac{Z_2' + Z_3'}{A'}, \quad Y_{si\ B} = \frac{Z_2^* + Z_3^*}{A^*},$$

$$Y_{gi\ A} = \frac{Z_1' + Z_3}{A'}, \quad Y_{gi\ B} = \frac{Z_1' + Z_3^*}{A^*}.$$

Knowing the input and mutual admittances, it is not difficult to find the voltage and power sensitivity.

Interchange of the positions of the source and galvanometer. The relations derived above easily solve the problem of the change in sensitivity when the positions of the source emf and galvanometer are interchanged.

It is clear from (7) that if the previous value of the emf E and the previous value of the matching factors of the impedances of the circuit with the impedances of the diagonals (k_s and k_g) are preserved during the interchange of positions, then the current sensitivity of the circuit is not changed. However, the value of the power being consumed in the circuit, as well as that transferred to the galvanometer in an unbalance of the circuit, is changed. In order to determine how the power sensitivity is changed, it is convenient to use (14).

If, during an interchange of the positions of the source and the galvanometer, the matching factors maintain an unchanged value, then the ratio of the power absorbed by the galvanometer to the total power absorbed by the circuit maintains its value, i.e.,

$$\frac{P'_{gx}}{P'_i} = \frac{P''_{si}}{P''_i}, \tag{16}$$

where

P'_{gz} and P'_i are the powers in the first position of the source and galvanometer;

P''_{gz} and P''_i are the powers in the second position.

From this, one can make certain conclusions concerning actual bridge circuits.

If the limiting condition in the design of a circuit is the value of the power dissipated in only one of the branches, for example, in the unknown branch, then the circuit will be more sensitive with that connection in which it has a larger input power for a given power in the unknown. For example, in the circuit shown on Fig. 3b, where $r_{10} = 100$ ohms, $r_2 = 200$ ohms, $r_3 = 400$ ohms, $r_4 = 800$ ohms, the power P'_i, supplied to the circuit when $I'_{10} = 0.01$ amp and the circuit is fed at the terminals SS, is equal to

$$P'_i = I'^2_{10}(r_1 + r_3) + I'^2_2(r_3 + r_4) = 3.75 \cdot 10^{-2} \text{ watt}$$

When the circuit is fed at the terminals GG and $I''_{10} = 0.01$ amp,

$$P''_i = I''^2_{10}(r_1 + r_3) + I''^2_2(r_3 + r_4) = 7.5 \cdot 10^{-2} \text{ watt}$$

Applying (16), it is easy to see that

$$\frac{P''_{gz}}{P'_{gz}} = \frac{P''_i}{P'_i} = \frac{7.5}{3.75} = 2,$$

that is, the power received by the circuit, and consequently also by the galvanometer, with the second connection (excitation through terminals GG) is twice as large as with the first (excitation through terminals SS). All this is with the condition that the power dissipated in the unknown arm and the matching factors in the two cases are the same. Let us examine a symmetrical circuit with a transformer (Fig. 6a). If the positions of the source and galvanometer are exchanged in this circuit, then we obtain a circuit with a differential transformer (Fig. 6b). Let us assume that the two circuits are balanced and the currents in the impedances Z_{10} and Z_2 in the two circuits are the same. Whereas the magnetic flux in the core and the current in the winding w_1 in the second circuit are zero, they are different from zero in the first circuit. The input power of the first circuit will be greater than the input power of the second circuit by the amount of the loss in the core and winding w_1. Therefore, if the reluctance of the core were the same with the two connections, it could be proved that the power transferred from the circuit to the unknown branch with an unbalance in the first circuit is somewhat larger than in the second. This conclusion remains unchanged when the variable reluctance of the core is taken into account. Actually, the core has a smaller reluctance in the operating regime in the first circuit than in the second, because in the latter case, the reluctance is determined by the value of the initial magnetic permeability of the core material. On the other hand, a decrease in the reluctance increases the sensitivity of the circuit (with other conditions remaining the same). Therefore, the above conclusion that the sensitivity of the first circuit is somewhat higher than the sensitivity of the second is also correct when the variable magnetic properties of the core are accounted for.

Unbalanced bridges. In the analysis of unbalanced bridge circuits, one is essentially interested in the dependence of the change of the current in the meter (galvanometer) on a change in the impedance of the unknown branch, and also in the sensitivity of the bridge to this change away from the balanced condition. In general form, this relation is expressed by the relation (see [2])

$$I_g = I_{g\infty} \frac{\lambda}{1 + \lambda}.$$

Here $I_{g\infty}$ is the current in the galvanometer with the unknown branch open-circuited;

$$\lambda = \frac{\Delta Z}{Z_{uu}},$$

where Z_{uu} is the input impedance of the bridge at the branch U when the circuit is balanced, i.e., when $Z_u = Z_{u0}$. It was shown there that S, the current sensitivity of the circuit to a change in the impedance Z_u away from the balanced condition, when balance is disturbed by a change in the impedance Z_u by the quantity ΔZ, is equal to $S = S_0/(1 + \lambda)$. Therefore, the nature of the dependence of I_g on Z_u is completely determined by the value of the input impedance Z_{uu} with the bridge balanced.

The calculation of Z_{uu}, like $I_{g\infty}$, is more complicated than the calculation of the input and mutual impedances of the diagonals, since Z_{uu} depends on the impedances of the latter.

In order to simplify the calculations, one can use the relation

$$Z_{uu} = \frac{S_0}{I_{g\infty}} \quad \text{(see [2])}$$

or

$$Z_{uu} = -\frac{1}{Z_{ug0}(1 + k_g)} \cdot \frac{I_{10}}{I_{g\infty}} \text{ i } Z_{uu} = \frac{E_{u\infty}}{I_{10}},$$

where $E_{u\infty}$ is the voltage at the terminals UU with the unknown branch open-circuited, and I_{10} is the current in the unknown branch when the circuit is balanced. Consequently, if the parameters of the balanced circuit are calculated, then in order to determine the current in the galvanometer for any value of ΔZ it is sufficient to calculate the current in the galvanometer or the voltage at the terminals UU with the unknown branch open-circuited. Since the calculation of these quantities is carried out for a simplified circuit (one of the branches opened), it is usually not too cumbersome.

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[2] M I. Levin, Elektrichestvo No. 2 (1946).

SPLIT BALANCING OF AC BRIDGES

N. N. Shumilovskii and V. Iu. Kneller

The conception of split balancing, which in practice means balancing with the minimum adjustment of bridge parameters, was formulated in [1, 2] after giving for the first time a clear and rigorous picture of bridge balancing not limited by assuming only small variations of variable parameters.

It is shown in [1, 2] that a necessary condition for split balancing is the use of a special indicator which shows the crossing point of the basic balancing lines. Both amplitude and phase differential indicators are used for this purpose. The use of differential instead of zero indicators, however, leads to additional errors which lower considerably the accuracy of measurement [3].

It is therefore of interest to attain split balancing with zero indicators connected to the measuring diagonal of the bridge.

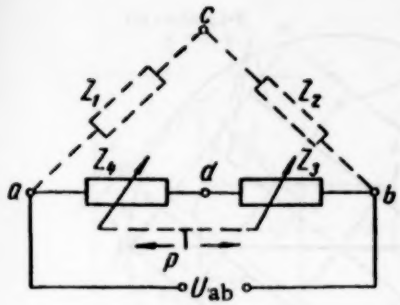

Fig. 1.

This becomes possible if the bridge balancing elements are connected in such a way that when they are adjusted at least the phase of the current in the corresponding arm remains constant. With such a connection the balancing line becomes straight instead of being circular as with a conventional connection, which considerably facilitates finding the crossing point of the basic balancing lines and makes the use of a zero indicator possible.

Let us examine a branch of an ac bridge (Fig. 1) consisting of two series impedances z_3 and z_4, which form the bridge arms. Let the adjustment of the impedances of this branch be made in such a manner that when the impedance of one of the arms is increased by $\underline{p}$ (normally a complex quantity) that of the other is decreased by the same amount $\underline{p}$, so that the current in the branch remains constant.

It is easy to show in a general form that the balancing line (i.e., the trajectory on a topographical diagram of the potential of point $\underline{d}$ at the bridge apex) will be a straight line.

In fact the balancing curve is usually determined by equation

$$\dot{U}_{ad} = \dot{U}_{ab}\frac{\dot{z}_4}{\dot{z}_3+\dot{z}_4}. \qquad (1)$$

In this case

$$\dot{z}_4 = \dot{z}_{40}+p; \quad \dot{z}_3 = \dot{z}_{30}-p, \qquad (2)$$

where $\dot{z}_{40}$ and $\dot{z}_{30}$ are constants.

Variable $\dot{p}$ can be represented in the form

$$\dot{p} = \dot{k}\alpha, \qquad (3)$$

where α is the rotation angle of the balancing element spindle, and $\dot{k}$ is the conversion factor.

If the balancing parameter is an ohmic resistance, $\dot{k}$ becomes a real number, if it is an inductance or capacity, $\dot{k}$ becomes imaginary.

Substituting (2) in (1) we have

$$\dot{U}_{ad} = \dot{U}_{ab}\frac{\dot{z}_{40}+\dot{p}}{\dot{z}_{40}+\dot{p}+\dot{z}_{30}-\dot{p}} = \dot{U}_{ab}\frac{\dot{z}_{40}+\dot{p}}{\dot{z}_{40}+\dot{z}_{30}} = \dot{A}\dot{p}+\dot{B}, \qquad (4)$$

where $\dot{A}$ and $\dot{B}$ are constants.

It follows from (4) that $\dot{U}_{ad}$ is a linear function of the complex variable $\underline{p}$, and hence is the trajectory of point $\underline{d}$ at a linear variation of $\underline{p}$, i.e., the balancing line is straight.

This can also be ascertained by examining the vector diagram of the bridge for each concrete case.

Let us now see how split balancing of the bridge is attained with this connection of the balancing elements.

When the balancing parameters consist of a resistance and a reactance in the same branch of the bridge, split balancing can be achieved with a normal zero amplitude indicator connected to the bridge diagonal (Fig. 2a). Figure 2b shows the topographical diagram of such a bridge (for a capacitative branch impedance) with balancing lines at α = var, β = const and β = var α = const.

Here α and β are rotation angles of the balancing element knobs, their values are determined from the bridge arm impedances:

$$R_3 = R_0 + k_1\alpha; \qquad x_3 = x_0 + k_2\beta;$$
$$R_4 = R_0 - k_1\alpha; \qquad x_4 = x_0 - k_2\beta.$$

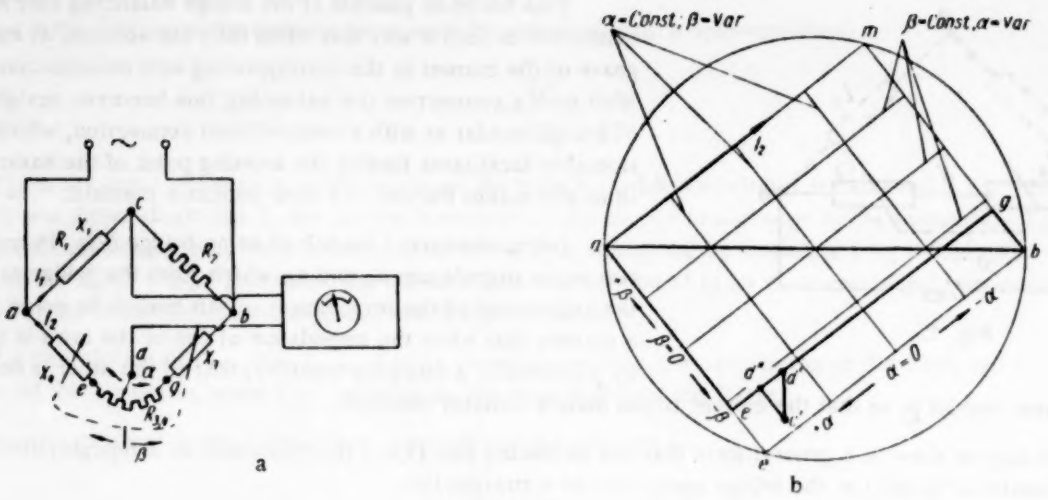

Fig. 2.

Let the potential at the bridge diagonal point c correspond to point c' on the topographical diagram and the potential at point d to point d'. The reading of the zero indicator will be determined by length c'd'.

By adjusting the position of knob α (varying the resistances of the arms) we move point d' along the line of balance α = var, β = const, to point d" which corresponds to the minimum value on the zero indicator. Since the balancing lines cross each other at right angles, point d" falls on a balancing line β = var, α = const, passing through point c'. Hence, by adjusting knob β (varying the reactances of the arms) for a zero reading on the indicator, we move the point corresponding to one end of the diagonal d to point c', i.e., we completely balancing the bridge.

Thus, due to the balancing lines being in this case straight and crossing each other at right angles, it is possible to move point d by following the zero amplitude indicator readings to any point on the topographical diagram (obviously within the rectangle ambe) by means of two consecutive adjustments of α and β , i.e., by means of split balancing.

The balancing does not change in principle with an inductive impedance of the branch adb.

It should be noted that, by an appropriate connection (Fig. 2a) of the balancing elements, split balancing was obtained with a zero indicator, but the possibility of separate reading which is valuable in many instances was lost.

Split balancing with a zero indicator can also be achieved, however, if one of the balancing elements is connected normally (Fig. 3a) and the other two balancing elements are in different arms of the bridge. Moreover with this connection it becomes possible to read off one of the components of the measured impedance from the value of one of the balancing parameters.

Since one of the balancing elements is now connected in the normal way it is no longer possible to attain split balancing with an amplitude zero indicator since the trajectories of the corresponding potential of the vertex of the bridge will now be circular. A zero phase-sensitive indicator (ZPSI) must now be used.

Split balancing of one of the many possible circuits of this type (Fig. 3a) with a ZPSI is explained in a topographical diagram (Fig. 3b).

The parameters of the phase shifting network (PSN) are selected in such a way that when switch S is in position I the ZPSI is fed with a reference voltage 90° out of phase with the current in branch adb (I_2) and in position II with a voltage in phase with current I_2 (and, hence, codirectional with the balancing line α = var).

Let the bridge vertexes c and d correspond on the topographical diagram to points c' and d'. Then with switch S in position I the reading of the ZPSI will be proportional to the projection of d'c' onto a line perpendicular to the line of balance α = var (c'd") and in position II it will be proportional to a projection of c'd' onto the line of balance α = var (d'd").

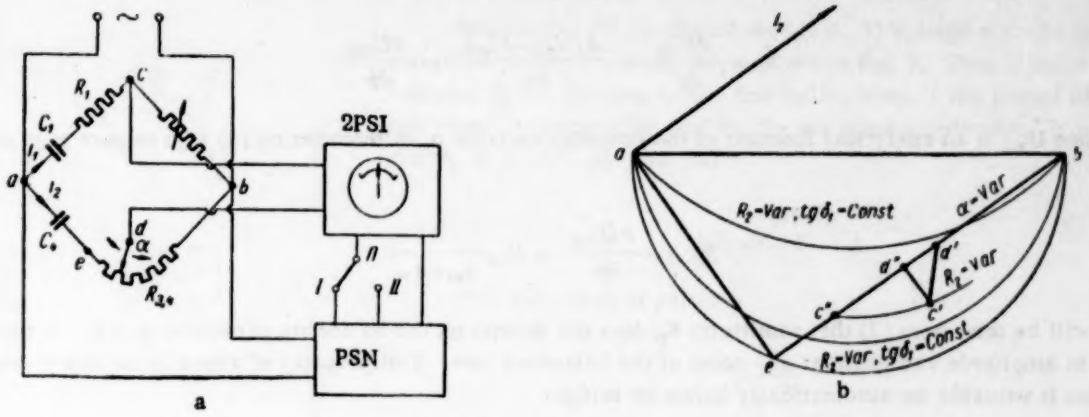

Fig. 3.

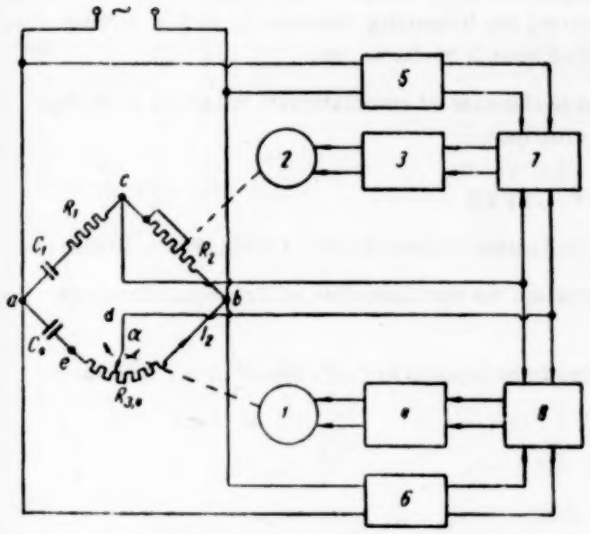

Fig. 4. 1,2) Servomotors; 3,4) servomotor amplifiers; 5,6) phase-shift networks; 7,8) phase sensitive zero indicators.

Having placed switch S in position I resistor R_2 is adjusted for a zero reading on ZPSI. The point on the diagram corresponding to apex c will then travel along the circumference from point c' to point c". Next having placed the switch in position II the diagram point corresponding to apex c is moved by means of slide wire $R_{3,4}$ (α) along the balancing line α = var from point d' to point c" thus completing the bridge balance.

Considering that $R_3 = R_0 + k$ and $R_4 = R_0 - k$ we obtain the formulas for C_1 and $\tan\delta_1$:

$$C_1 = C_4\frac{R_0 + k\alpha}{R_2}; \quad tg\delta_1 = \omega C_1 R_1 = \omega C_4(R_0 - k\alpha). \quad (5)$$

It will be seen from (5) that in this case $\tan\delta_1$ can be obtained from one parameter only (α).

Above connection of balancing elements which provides split balancing with zero indicators can become extremely useful for ac automatic bridges.

It is known that automatic ac bridges with ZPSI and a normal connection of balancing elements have interacting balancing circuits [1, 3]. This interaction can be eliminated or at least greatly reduced if above connections of balancing elements are used which in a number of cases will improve the dynamic properties of automatic bridges.

Thus, for instance, in the automatic bridge (Fig. 4) based on the circuit of Fig. 3a, the movement of servomotor 1 which controls slide wire $R_{3,4}$ will not affect the movement of servomotor 2, which controls slide wire R_2, when the reference voltage for the ZPSI in position I is at 90° to current I_2 (and codirectional with the balancing line α = var). This can be easily seen from the topographic diagram of the bridge (Fig. 3b). This bridge thus eliminates one of the couplings between the balancing circuits and hence the interaction between the controls.

In automatic bridges based on the circuit of Fig. 2a it is possible to eliminate both couplings between the balancing circuits. In such an instance, however, it would be necessary to use a phase-sensitive instead of a zero-amplitude indicator, since an automatic bridge indicator must show not only the size but also the direction of the deviation from balance. For this purpose the reference voltage phase of the ZPSI controlling resistor $R_{3,4}$ must be in phase with current I_3 and that of the ZPSI controlling the reactance $x_{3,4}$ at 90° to current I_2.

Let us examine briefly the sensitivity of the bridge circuit when balancing elements are connected according to Fig. 1. We assume as is usual for ac bridges electronic indicators that the input impedance of the indicator is high.

The bridge voltage sensitivity with a varying $\underline{p}$ (Fig. 1) will be:

$$\dot{S}_p = \frac{\partial \dot{U}_{dc}}{\partial \dot{p}} = \frac{\partial (\dot{U}_{ad} - \dot{U}_{ac})}{\partial \dot{p}} = \frac{\partial \dot{U}_{ad}}{\partial \dot{p}}. \tag{6}$$

Since $\dot{U}_{ad}$ is an analytical function of the complex variable $\underline{p}$, differentiating (4) with respect to $\underline{p}$ we obtain

$$S_p = \frac{\partial \dot{U}_{ad}}{\partial \dot{p}} = \dot{U}_{ab} \frac{1}{z_{40} + z_{30}} \tag{7}$$

It will be seen from (7) that sensitivity S_p does not depend on the balancing parameter $\underline{p}$, i.e., it remains constant in amplitude and phase at any point of the balancing line. This property of above balancing elements connection is valuable for automatically balanced bridges.

SUMMARY

1. The theoretical possibility of split balancing ac bridges with zero indicators connected across the bridge diagonal is demonstrated. This is rendered possible by connecting the balancing elements in such a manner that their adjustment does not affect the current in the corresponding branch of the bridge.

2. Above connection of balancing elements eliminates in the case of automatically balanced ac bridges (or at least greatly reduces) the interaction of the balancing circuits.

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DC AMPLIFIERS WITH CONTACT TRANSDUCERS

G. I. Levitan

DC amplifiers with contact transducers which convert the measured dc voltage into an ac voltage have found a wide application in measuring instruments. The main advantage of these amplifiers is the absence of zero drift. Although several designs of such amplifiers have been described in the technical literature, many most important questions of their design have as yet not been dealt with.

In the Leningrad Exploration Laboratory of the All-Union Scientific Research Institute for the Technique and Technology of Exploration the author and L. M. Ioffe constructed a portable dc amplifier with a sensitivity of 50 μv and an input impedance of 2.5 meg with a very small reactance. Below certain properties of such amplifiers with contact transducers are analysed.

Stability of a contact transducer. Special vibrating converters or polarized relays are usually used as contact transducers. In high input impedance amplifiers the instability of contacts is of secondary importance.

Large errors can be caused by the instability of the relation between the rectangular pulse half-periods obtained as the result of conversion.

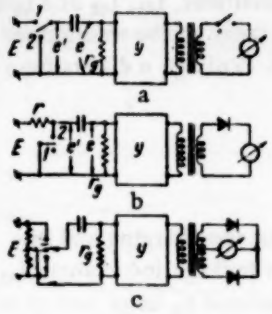

Fig. 1.

Irrespective of the circuit used (Fig. 1) voltage e at the input of the ac amplifier Y has the shape shown in Fig. 2. Here E is the measured voltage, T_1 the duration of the first half-period, T the period of the converter's commutation and E_b, E_H are pulse amplitudes. It is assumed that $r_g \gg r$. It is obvious that

$$E = E_b + E_H. \tag{1}$$

$$E_b T_1 = E_H (T - T_1). \tag{2}$$

The duty ratio of pulses is

$$\gamma = \frac{T_1}{T}. \tag{3}$$

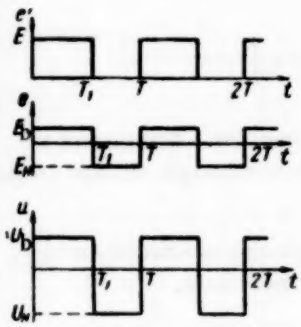

Fig. 2.

Let us assume that the amplifier does not introduce any distortion and that the output voltages are $U_b = kE_b$ and $U_H = kE_H$ (k is the gain of the amplifier).

Let the rectification of the output voltage u be carried out by a pair of contacts (Fig. 1a) which open and close in synchronism with input converter or by means of a rectifier (Fig. 1b and 1c). The reading of the moving coil instrument will then be proportional to the mean value of current i_0:

$$i_0 = \frac{U_b T_1}{TR} = \gamma \frac{U_b}{R}$$

or

$$i_0 = \frac{U_H (T - T_1)}{TR} = (1 - \gamma) \frac{U_H}{R},$$

where R is the rectifier load resistance.

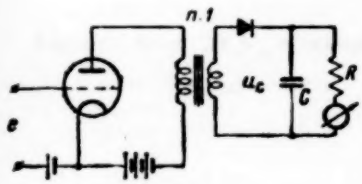

Fig. 3.

With full-wave rectification the value of i_0 is doubled.

It is obvious that

$$U_b = k(1 - \gamma)E, \tag{4}$$

$$U_H = k\gamma E, \tag{5}$$

$$i_0 = \frac{k}{R} \gamma (1 - \gamma) E. \tag{6}$$

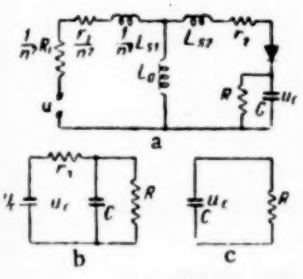

Fig. 4.

The optimum value of the pulse duty ratio is $\gamma = 0.5$. Then the derivative

$$\frac{di_0}{d\gamma} = \frac{k}{R}(1 - 2\gamma)E \tag{7}$$

is equal to zero and the instrument readings are affected but little by the duty ratio. Variation of the duty ratio by ± 10% from the optimum of $\gamma = 0.5$ will cause changes in current i_0 of 0.8%. Variation of the duty ratio by ± 25%, however, will cause a considerable error in measurement of the order of 6.5%.

Let us note that all the conclusions regarding the effect of the pulse duty ratio also hold for full wave rectification (Fig. 1c).

In order to smooth the current flowing through the instrument or the loop of an oscillograph the circuit shown in Fig. 3 is often used. Voltage e is rectangular, of an amplitude E_c and a pulse duty ratio $\gamma = 0.5$. An equivalent circuit referred to the secondary of the transformer is shown in Fig. 4a. Here μ and R_i are the parameters

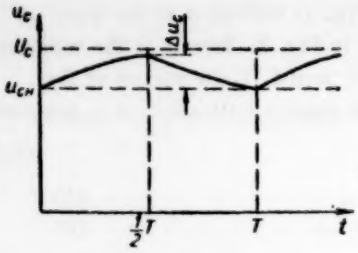

Fig. 5.

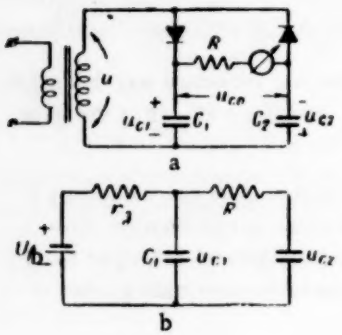

Fig. 6.

of the amplifier tube, working under linear conditions, L_{s1}, L_{s2} and L_0 are the leakage inductances and the primary inductance of the transformer and r_1 and r_2 are the resistances of its windings. Voltage u differs from e in amplitude by

$$U_c = \frac{\mu}{n} E_c.$$

Figure 4b shows the equivalent circuits for the charging and discharging of capacitor C. It is assumed that the leakage inductances L_{s1} and L_{s2} are small enough and the primary inductance L_0 large enough to have only a small effect on the charging process. It will be shown later that the condition $R \gg r_3$ is always fulfilled. The time constant of the charging circuit is then equal to

$$\tau_3 \simeq r_3 C = \left[\frac{1}{n^2}(R_i + r_1) + r_2 + r_b \right]$$

Here r_b is the forward resistance of the rectifier. The reverse resistance is assumed to be infinitely large. The steady-state voltage across the capacitor has the shape shown in Fig. 5.

By making time t coincide with the beginning of charging or discharging it is possible to write for voltage u, respectively,

$$u_c = U_c - (U_c - u_{cH}) e^{-t/\tau_3},$$

$$u_c = (u_{cH} + \Delta u_c) e^{-t/\tau_p}.$$

In order to ensure efficient smoothing of voltage u_c the discharge time constant $\tau_p = RC$ must be much greater than T/2. Moreover

$$u_{cH} \simeq (1 - A) U_c, \quad \text{where} \quad A = \frac{T}{2\tau_p} \frac{1}{1 - e^{-T/2\tau_3}}.$$

The mean value of voltage across the capacitor is

$$u_{co} = \frac{1}{T} \int_0^T u_c dt$$

Integrating and considering that

$$e^{-T/2\tau_p} \simeq 1 - \frac{T}{2\tau_p} + \frac{1}{2}\left(\frac{T}{2\tau_p}\right)^2$$

we obtain an expression for the relative error of measurement introduced by the rectifier circuit:

$$x = \frac{U_c - U_{co}}{U_c} = \frac{1}{8} \frac{T}{\tau_p} \left(1 + \frac{2}{e^{-T/2\tau_3} - 1} \right) + \frac{\tau_3}{2\tau_p} \qquad (8)$$

It will be seen from (8) that by increasing τ_p and decreasing τ_3 it is possible to obtain an arbitrarily small value for x. As small a value as possible should be chosen for resistor r_3 since then the capacity of C can be increased and R decreased and, hence, the sensitivity of the circuit raised. However the voltage fed to the rectifier must not be smaller than 2 to 3 volts (over the whole range) in order to make the nonlinear lower part of the characteristic relatively small.

In order to ensure a small resistance for r_3 it is necessary to select a tube with a small anode resistance R_i

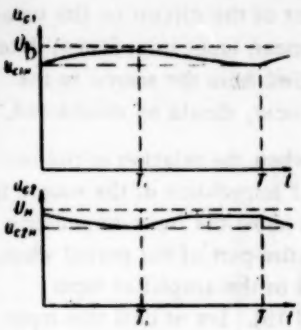

Fig. 7.

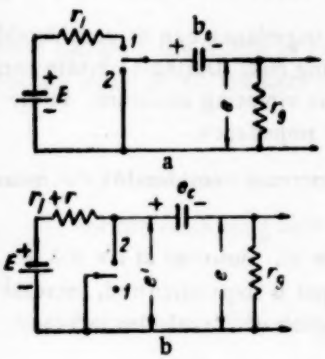

Fig. 8.

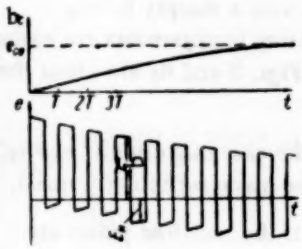

Fig. 9.

(a triode), a transformer with a sufficiently high transformation ratio n and small losses in the windings and a rectifier with a small forward resistance.

It is useful to use a negative voltage feedback, since this decreases R_i.

In this rectifier circuit (with the above parameter relations) the readings of the instrument will be proportional to the amplitude of the voltage pulses E_c. If follows from (4) and (5) that the duty ratio instability effect in this instance will be very large.

In order to eliminate this error a dc negative feedback round the contact transducer is suggested in [1, 2]. The defect of such a system especially for nonreactive devices is the necessity for careful smoothing of the feedback voltage fed to the input of the amplifier. This leads to the introduction of reaction into the system.

Heavy negative dc feedback is not the only method of eliminating errors due to duty ratio instability. In fact if the current through the instrument is made proportional to the sum of the output amplitudes ($U_b + U_H$) its value will be independent of the duty ratio. From (4) and (5) we have:

$$i_0 = \frac{U_b + U_H}{R} = \frac{k(1-\gamma)E + k\gamma E}{R} = k\frac{E}{R}. \qquad (9)$$

This condition can be easily ensured in a full wave voltage rectifier, where circuit is shown in Fig. 6a. Stability of sensitivity is provided by a negative feedback in the ac amplifier circuit. The charging of C_1 and discharging of C_2 which occur simultaneously during one half-period can be studied by means of the equivalent circuit shown in Fig. 6b. The same assumptions and notations are adopted here as before (Fig. 4). If capacities C_1 and C_2 in Fig. 6b are interchanged and U_b is substituted by $-U_H$, this circuit will represent the charging of C_2 and discharging C_1 which occur in the second half-period. Figure 7 represents the graphs of u_{c1} and u_{c2} in a steady state. It can be shown that voltages u_{c1} and u_{c2} are equal to

$$u_{c1H} = (1-B_1)(1-\gamma)(U_s + U_H), \quad u_{c2H} = (1-B_2)\gamma(U_b + U_H),$$

where

$$B_1 \simeq \frac{T}{\tau_p}\frac{1}{1-e^{-\gamma T/\tau_3}}, \qquad B_2 \simeq \frac{T}{\tau_p}\frac{1}{1-e^{-(1-\gamma)T/\tau_3}}.$$

The sum of u_{c1H} and u_{c2H} is equal to

$$u_{c1H} + u_{c2H} = [1-(1-\gamma)B_1 - \gamma B_2]\,(U_b + U_H). \qquad (10)$$

By choosing a sufficiently large τ_p and a sufficiently small τ_3 the voltage ($u_{c1H} + u_{c2H}$) can be made arbitrarily close to the voltage ($U_b + U_H$). This makes the instrument reading independent of the duty ratio.

It can be shown that at $\gamma = 0.5$ the error

$$x = \frac{(U_b + U_H) - u_{c0}}{(U_b + U_H)}$$

is exactly twice as large as the value calculated from (8); u_{c0} is the mean value of voltage ($u_{c1} + u_{c2}$).

Input impedance. The input impedance of a transducer should be defined more precisely. When it is

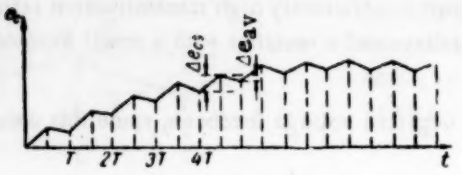

Fig. 10.

m	(end of the first half-period)	Δe_{cs}	(end of the second half-period)	Δe_{av}
1	δE	δE	$\delta E - \delta^2 E$	$\delta^2 E$
2	$2\delta E - 2\delta^2 E$	$\delta E - \delta^2 E$	$2\delta E - 4\delta^2 E$	$2\delta^2 E$
3	$3\delta E - 6\delta^2 E$	$\delta E - 2\delta^2 E$	$3\delta E - 9\delta^2 E$	$3\delta^2 E$
4	$4\delta E - 12\delta^2 E$	$\delta E - 3\delta^2 E$	$4\delta E - 16\delta^2 E$	$4\delta^2 E$

required to know the effect of the circuit on the measured voltage source the mean input impedance, determined by the power supplied from the source to the input circuit of the transducer, should be considered.

On the other hand when the relation of the output voltage to the internal impedance of the source is required it is necessary to know the input impedance of the circuit only during the part of the period when the measured signal is fed to the amplifier input (position 1 in Figs. 1a and 1b). Let us call this input impedance the operating impedance. The operating impedance in circuits of Figs. 1a and 1b is equal to r_g or $(r + r_g)$ and can be easily made sufficiently large.

The mean input impedance can be considerably smaller than the operating one. During a certain part of the period (up to 7% [3]) the stationary contacts of the transducer are closed by the vibrating armature. In circuits of Figs. 1a and 1b this will lead to a sharp drop in the value of the mean input impedance.

It is shown in [1] that the application of a heavy dc negative feedback will increase considerably the mean input impedance of the circuit.

It is advisable to make resistance r (Fig. 1b) sufficiently large (keeping $r_g \gg r$). However at $r > 0.3$ to 0.5 meg the parasitic signal, which appears on the grid of the first tube when the input is short circuited, increases considerably (due to grid currents). With a large r the pickup from the transducer excitation coil also increases.

Circuit lag. A small lag is required in a dc amplifier with a contact transducer when, for instance, the device is used to measure changing dc voltages. The lag of the instrument is determined in the main by the smoothing filter of the rectifier. For efficient smoothing in the circuits of Figs. 3 and 6a the filter time constant RC must be sufficiently large. On the other hand for a normal operation of the circuit with a sharply falling measured voltage this time constant must be made sufficiently small. These contradictory requirements are easier to meet when the conversion frequency is high. It should be noted that the circuits in Figs. 3 and 6a are about the same with respect to lag.

With a sharply rising measured signal the lag depends on the time constant of the charging circuit $\tau_3 = r_3 C$. Since it is not difficult to make $\tau_3 \ll T$, the duration of the signal leading edge can be made sufficiently small.

A small lag is much easier to obtain in a full-wave rectifier circuit (Fig. 1b). If the rectified pulses are close to a rectangular shape and have a duty ratio of $\gamma = 0.5$ no smoothing filter is required in the circuit of Fig. 1b.

Peculiar distortions appear in the output circuit with sudden changes of the input voltage. In Fig. 8 r_i is the internal impedance of the measured voltage source. Let the measured voltage change suddenly from zero to E at instant $t = 0$. Figure 9 shows a simplified graph of voltage e_c across capacitor C (the actual graph of e_c is shown in Fig. 10) and the graph of voltage e. It is assumed that $r_g C \gg T$. If the time constant of the circuits connecting the ac amplifier stages is large the shape of the voltage at the input of the rectifier will be similar to that of voltage e in Fig. 9.

If half-wave rectification is used, an overshoot will appear in the recorded impulse shape (if the top pulses E_b are rectified) or the leading edge will be extended (if the bottom pulses E_H are rectified).

If full-wave rectification is used without a smoothing filter (Fig. 1c) the mean current value for a period in the measuring device is (Fig. 9).

$$i_0 = \text{const}\,[E_b T_1 + E_H (T - T_1)].$$

If $T_1 = 0.5\ T$ ($\gamma = 0.5$) current i_0 will be proportional to the voltage swing $E = E_H + E_b$. For full-wave voltage rectification (Fig. 6a) this conclusion holds for any values of γ.

Let us now show that errors in reading can be made negligible when circuits of Figs. 1c and 6a are used.

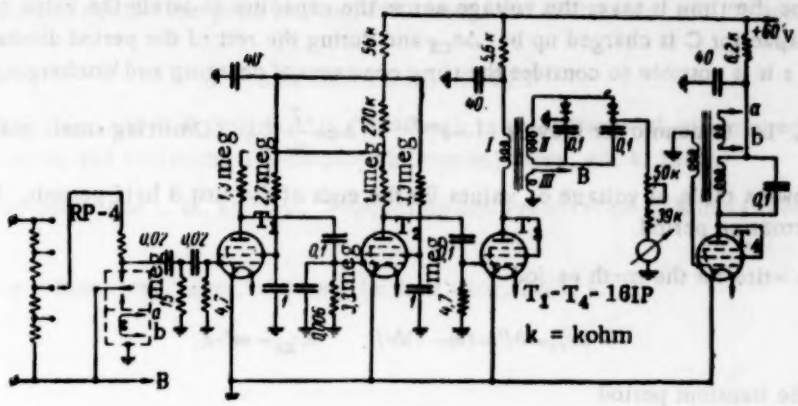

Fig. 11.

Since $r_g C \gg T$ the height of each pulse (E_b or E_H) throughout its length can be considered practically constant. We can write for all the half-periods corresponding to the switch position 1,

$$e = E_b = \alpha(E - e_c), \text{ where } \quad \alpha = \frac{r_g}{r + r_g}.$$

For the remaining half-periods (position 2)

$$e = E_H = e_C.$$

Immediately following the impulse (t = 0)

$$e_c = 0; \quad E_b = \alpha E; \quad E_H = 0; \quad (E_b + E_H)_0 = \alpha E.$$

After the voltage has reached its stable state across the capacitor

$$e_c = e_{c\,st}, \quad E = \alpha(E - e_{c\,st}), \quad E_H = e_{c\,st},$$
$$(E_b + E_H)_{st} = \alpha E + (1 - \alpha) e_{c\,st}. \tag{11}$$

In order to find $e_{c\,st}$ let us note that voltage e' (Fig. 8b) has the shape of a rectangular pulses with amplitude $E' = E - r i_{c\,st}$.

Here

$$i_{c\,st} = \frac{E - e_{c\,st}}{r + r_g}$$

is the current passing through r and r_g when the switch is in the first position. It is possible to write that $e_{c\,st} = \gamma E'$. From this it is easy to find that

$$e_{c\,st} = \frac{\gamma \alpha E}{1 - \gamma(1 - \alpha)} \approx \gamma \alpha E.$$

Substituting this expression in (11) we obtain

$$(E_b + E_H)_{st} = [1 + (1 - \alpha)\gamma] \alpha E.$$

The error caused by variations of ($E_b + E_H$) in the stabilization process is

$$\frac{(E_b + E_H)_{st} - (E_b + E_H)_0}{(E + E_H)_0} = (1 - \alpha)\gamma. \tag{12}$$

It is obvious that α should be as close to unity as possible. If, for instance, $\gamma = 0.5$, r = 0.4 meg, and r_g = 10 meg, the error will amount to 2%.

Let us determine the time it takes the voltage across the capacitor to attain the value of e_c. In the first half of each period capacitor C is charged up by $\Delta e_{cз}$ and during the rest of the period discharged by Δe_{cp} (Fig. 10). Assuming $r_g \gg r$ it is possible to consider the time constants of charging and discharging to be the same and equal to $\tau = r_g C$. Let us denote for brevity $1-e^{-T/2\tau} = \delta \simeq \frac{T}{2\tau} \ll 1$. Omitting small quantities of higher orders, let us write down a table of voltage e_c values for the ends of the first 8 half-periods. Here m is the ordinal of the transformation period.

It is possible to write for the m-th period

$$\Delta e_{cз} = \delta E - (m-1)\delta^2 E; \qquad \Delta e_{av} = m\delta^2 E.$$

At the end of the transient period

$$\Delta e_{cз} = \Delta e_{av}$$

or

$$\delta E - (m-1)\delta^2 E = m\delta^2 E.$$

Solving this equation for m we have

$$m = \frac{1}{2}\left(1 + \frac{1}{\delta}\right) \simeq \frac{1}{2\delta} = \frac{\tau}{T}.$$

The duration of the transient process is

$$mT = \tau. \tag{13}$$

By decreasing τ it is possible to make above process sufficiently short. However a decrease of capacity C down to a value at which $\tau = r_g C$ is comparable with T will lead to a sharp distortion in the rectangular shape of the pulses, which is highly undesirable since it will require an increase in the time constant of the rectifier smoothing filter.

Circuit of the instrument. The schematic of the finally developed instrument is given in Fig. 11.

Polarized relay type RP-4 was used as a contact converter; the frequency of oscillation was 80 cps, power consumed by it was 1 to 2 mw. The serviceability of the relay was tested by making it work for 150 hours without a break during this time the pulse duty ratio did not vary by more than 6%. In order to avoid pickup on the contacts from the excitation winding the latter was screened electrostatically. The relay was placed in a steel container.

When the polarity of the measured voltage was changed the output instrument reading changed a little (there appears to be added to the measured voltage a stray dc voltage which arises in the instrument itself). With a measured voltage of 5 mv the difference in reading amounts to 30 μv referred to the input.

The range of the instrument is 5 mv to 5 v (full scale). The input potential divider is assembled from precision resistances type BLP and MLP which are not wire-wound and provide a total resistance of 2.5 meg.

The coupling capacitor in the grid of the first tube must have a very small leakage, since for a voltage drop of the order of 40 μv across resistor r = 0.4 meg a current of only 10^{-10} amp is required. A parallel resistor of 15 meg (Fig. 11) lowers the insulation requirements of this capacitor.

The total gain determined as the ratio of the pulse swing at the primary winding of the output transformer to the dc input voltage is equal to 7200. The feedback from winding III of the output transformer reduces the gain by a factor of 3.5. The feedback from the 270 kilohm resistor (Fig. 11) reduces the gain by another factor of 3.2. The feedback provides a stable gain with heater voltage changes of 1 to 1.4 v and anode voltage changes of 60 to 80 v.

Readings remain stable with pulse duty ratio variations of ± 30% from $\gamma = 0.5$.

With dc rectangular pulses the pulse rise and fall times were of the order of 0.05 sec.

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HIGHLY SENSITIVE METHOD OF MEASURING MAGNETOSTRICTION

S. I. Voskoboinikov

Measurements of magnetostriction are now made by means of opticomechanical or extensometric methods, which are sufficiently sensitive and simple to use. In the opticomechanical method the variations in the length of the ferromagnetic sample due to the variations of the surrounding magnetic field are measured by means of a system of mechanical levers with an optical projection. This method is used in measuring devices of various designs [1, 2, 3]. The highest sensitivity is attained in Kornetskii's magnetostriction meter [1] improved by Selisskii [2].

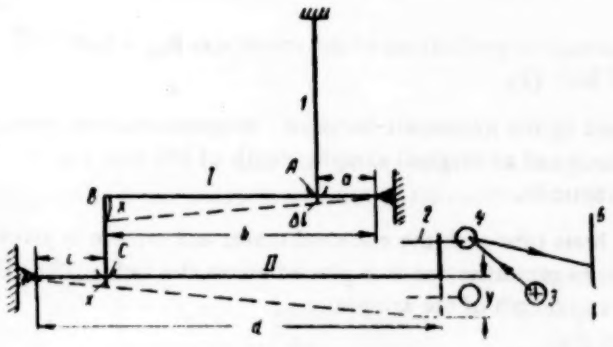

Fig. 1.

A description is given below of the opticomechanical meter developed by the author, made at the TsNIIChERMET and differing from other such meters by its double lever of the second order whose end rotates a pointer with a mirror.

The magnetostriction meter (Fig. 1) consists of levers I and II, of lengths b and d respectively, fixed at one end to stationary supports. The other end of lever I is connected to lever II at point C and the free end of lever II is connected to axle 2 to which mirror 4 is attached. The measured sample 1 is fixed at one end to a stationary support in such a manner that its other end touches lever I in point A at distance a from the fixed end of the lever. Illuminator 3 throws a beam of light on mirror 4 which reflects it onto scale 5. Any variations in length of the sample displace point B of lever I in either direction by a distance x, moving in turn the end of lever II by a distance y which turns axle 2 with mirror 4 thus displacing the beam of light along scale 5.

The magnification of the magnetostriction meter is equal to

$$K=\frac{\Delta L}{\Delta l}=\frac{2i_m R}{D}, \qquad (1)$$

where ΔL is the displacement of the light spot along the scale due to the rotation of axle 2 with mirror 4.

Δl is the change in the length of the sample under magnetization, $i_m = b/a \cdot b/c$ is the gear ratio of the system of levers, R is the distance between the mirror and the scale, and D is the axle diameter.

In the case of this meter D = 0.5 mm, i_m 5 × 5 and R = 1000 mm, hence,

Fig. 2.

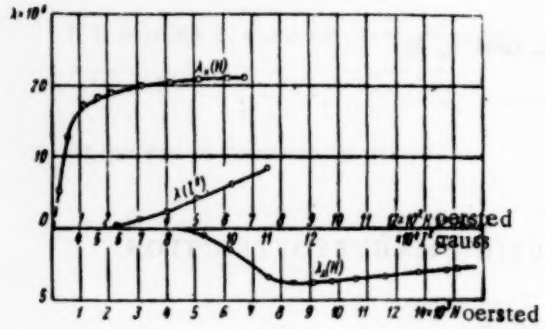

Fig. 3.

$$K = \frac{2 \cdot 25 \cdot 1000}{0.5} = 10^5.$$

The construction of the meter, which is mounted in a brass tube with an appropriate slot, is shown in Fig. 2.

Lever I in the shape of a rectangular block 3 mm long, 5 mm wide and 15 mm high is fixed to half-ring 4 by means of a short, 0.1 mm thick phosphor-bronze plate which is soldered to the bottom end of the lever and to the half-ring. Socket 5 is soldered to lever I at a distance of 3 mm from its bottom end, this socket takes one end of test sample 1 fixed in it by a screw. The other end of the sample is fixed also by means of a screw in socket 6 of the holder made in the shape of a semicylinder.

Lever II, 50 mm long is mounted on brass plate 7 which is bolted to the brass cylinder. One end of the lever is soldered to the brass pin 8 by means of the short thin phosphor bronze plate 9 and the other end rests on the 0.5 mm diameter cylindrical axle 2 which lies partly on plate 7 and is lightly pressed against it by the free end of lever II. One end of axle 2 carries the mirror and the other a small counterbalancing weight. Levers I and II are connected by duralumin rod 10, one end of which is firmly fixed to the top end of lever I and the other to lever II at point C 10 mm from its stationary end. The illuminator and the scale (in the shape of an arc 1 m in diameter) are placed at a distance of 1 m from the mirror.

The meter was calibrated by means of nickel samples since the magnetostriction of nickel has a constant sign and is sufficiently well known.

As the result of calibration it was found that the actual magnification of the meter was $K_{ef} = 1.01 \cdot 10^5$ which agrees well with the theoretical value calculated from (1).

For comparison purposes we quote the data obtained by the Kornetskii-Selisskii magnetostriction meter [2]. With the scale placed at 3.28 m away from the mirror and an original sample length of 200 mm $K_{ef} = 0.132 \cdot 10^5$. Both meters have axles 2 of the same diameter D.

When measuring longitudinal magnetostriction the brass tube with the enclosed meter and sample is placed along the magnetic field and when measuring transverse magnetostriction it is placed across the field. The effect of the field is determined in both cases by the variations in length of the sample.

The following additional errors may arise during measuring.

1. Deviations in measurements can occur with repeated fixing of the same sample due to differences in spring strain and variations in the degree of tightening by means of the holder screw.

In order to determine this error, measurements were repeated 8 times. After each measurement the sample was taken out of the meter and heated to a temperature exceeding the Curie point. The deviations in measurements did not then exceed 1.5%.

2. Considerable strain in the meter springs due to the tendency of the sample to turn its longitudinal axis along the direction of the magnetic field when transverse magnetostriction is measured.

In order to stop the sample from turning in a transverse magnetic field, two short thin phosphor bronze strips are soldered to the brass tube; their free ends are soldered to the opposite sides of the sample. These strips bend easily when the length of the sample changes but offer resistance to a turning movement. The efficiency of this method was checked by measuring the longitudinal saturated magnetostriction of three nickel samples in a magnetic field of a solenoid. At first the samples were measured without being soldered to the strips and then in the soldered position. In comparing the saturated magnetostriction in the two cases it was found that the largest difference amounted to 2%. Next the same samples were measured for transverse magnetostriction. The

thus obtained results had the opposite signs and were half the longitudinal magnetostriction value, which agrees with the data contained in the technical literature.

The maximum relative error of measurement of the longitudinal magnetostriction is 4% and that of the transverse magnetostriction is 5%.

Figure 3 shows curves of the longitudinal $\lambda_{\parallel}$ (H) and transverse $\lambda_{\perp}$ (H) magnetostriction plotted against the external magnetic field H and the curve of the relation between the longitudinal magnetostriction λ (I^2) of an alloy containing 54% nickel, 41% iron and 4.6% cobalt and the square of the magnetizing force I.

SUMMARY

Above opticomechanical meter for measuring static magnetostriction of a different design to the existing ones has the following advantages: a constant magnification independent of the position of the light spot, greater sensitivity and the possibility of measuring both longitudinal and transverse magnetostriction.

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TECHNIQUE OF MEASURING DYNAMIC MAGNETOSTRICTION

V. I. Skorobogarov

In order to evaluate the performance of a magnetostriction vibrator and find suitable materials for its construction it is necessary to measure magnetostriction in alternating magnetic fields (dynamic magnetostriction).

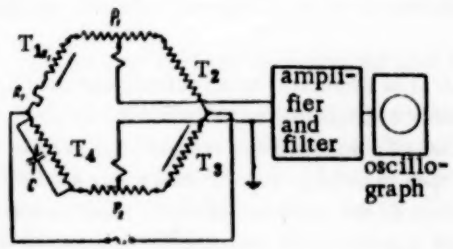

Fig. 1.

The value of dynamic magnetostriction is often judged by the effects produced by the vibrator, for instance, by the height of the fountain of liquid or the spray above the vibrating surface, by the size of cavitation or by the diffusion of a beam of light reflected from the end of the vibrator and observed through a microscope.

Above methods can hardly give a clear picture of the character of the vibrator's movement and certainly cannot provide curves of the vibrator's displacements.

Until recently the only method of measuring dynamic magnetostriction which to a certain extent satisfied these requirements was the capacity method.

The application of resistance type wire strain gauges and wire transducers opened up new possibilities for measuring static and dynamic magnetostriction.

The article deals with the technique of measuring dynamic magnetostriction by means of wire transducers, a technique which provides curves of the vibrator's movement for different conditions of its operation.

Above technique is based on an ac bridge circuit consisting of wire transducers with its measuring diagonal connected to an amplifier (Fig. 1). Due to the magnetostriction sample and the transducers being in an alternating magnetic field, an emf appears in the transducer windings which hinders the measurement of magneto-

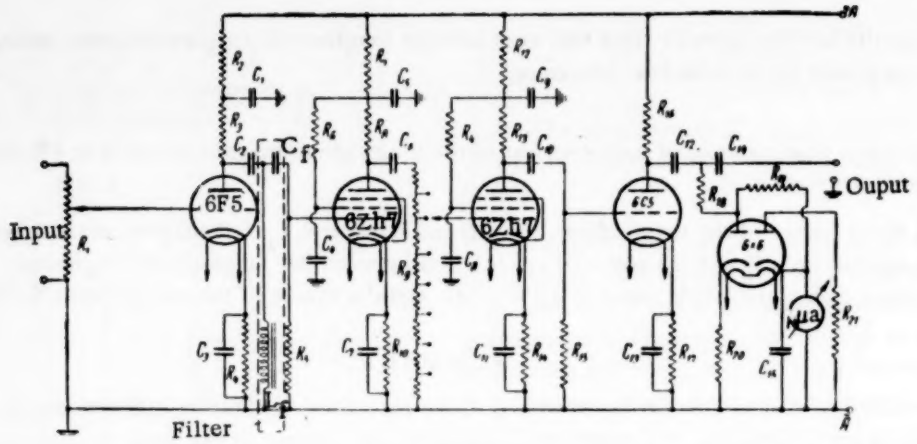

Fig. 2.

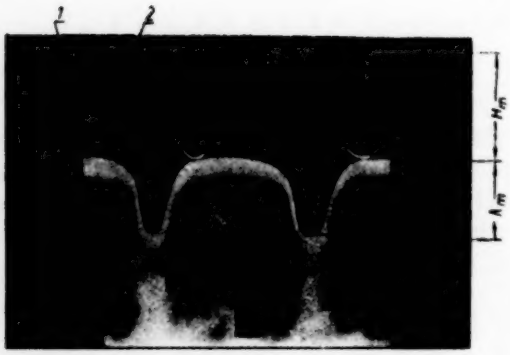

Fig. 3.

striction strains. Therefore the elimination of the induced emf effect becomes an important consideration in working out the method of measuring dynamic magnetostriction. The emf's appear in the transducer windings due to the stray magnetic field of the sample.

Certain peculiarities of amplitude modulation and a high pass filter were used in the suggested circuit in order to avoid the induced emf effect.

If the alternating current of frequency f flowing in the arms of the bridge is modulated by the magnetostriction frequency f_0 currents of frequencies f, $f + f_0$ and $f - f_0$ will flow in the measuring diagonal of the bridge. In addition a current of frequency f_0 due to the induced emf will also flow through the diagonal.

Since in amplitude modulation f is always chosen to be considerably larger than f_0, the current due to the interfering emf can be easily filtered out. This is attained by a high pass filter connected between the first and second amplifier stages (Fig. 2). This bridge, built up of transducers, represents a peculiar mechanical modulator in which mechanical magnetostriction vibrations in straining the transducers alter their resistance, thereby modulating the bridge current.

In obtaining dynamic magnetostriction curves of various materials it is important to select appropriate frequencies of vibration. If the vibration frequency is close to the resonance frequency of the sample, its dimensions will affect the shape of the curves and at frequencies above that of resonance the sample will lag behind the field variations causing distortion of the curves appropriate to that material. On this basis it is advisable to select the vibration frequency much lower than the resonance frequency of the sample. In these experiments the frequency of the magnetizing field was taken at 50 or 400 to 600 cps depending on the size of the sample. At the same time the bridge was fed with a current of 2000 or 10000 cps.

All the transducers are mounted close to each other and placed together into the magnetizing coil. Transducers T_1 and T_2 are operative (See Fig. 1) and are attached to the sample reproducing its magnetostrictive strains. In order to compensate for the possible strains in the sample due to its bending in the alternating magnetic field, the operative transducers are attached on two opposite sides of the sample.

The compensating transducers T_2 and T_4 serve as normal arms of the bridge and are placed together with operative ones inside the magnetizing coil in order to provide for them the same temperature conditions.

The bridge is balanced by means of two slide-wire potentiometers P_1 and P_2 and a variable capacitor C, which is mounted in a separate screened box and is connected to the transducers by means of screened leads. Two potentiometers provide a smooth adjustment of the bridge. The small resistor R_T serves to calibrate and check the stability of the circuit.

The bridge is fed from an audiofrequency tube oscillator with a wave form close to a sinusoidal shape. The presence of higher harmonics in the supply voltage produces across the measuring diagonal of the bridge an unbalanced voltage which due to the high gain of the set leads to distortion of the magnetostriction curves. The total amplitude of all the higher harmonics must not, therefore, exceed a definite value depending on the sensitivity of the amplifier.

The measuring amplifier is RC coupled (Fig. 2) and consists of four amplifying stages. The output of the amplifier is connected to a moving-coil instrument which provides a reading of the value of magnetostriction. The output voltage can also be connected to an input of an oscillograph. The four amplifying stages are not indispensable since the full gain of the four is very seldom used. The basic requirement of the amplifier is the linearity of its amplitude characteristic.

The calibration of the set and checking of its stability is achieved by means of a small calibrating resistor connected in the ac bridge circuit. Knowing the value of the calibrating resistor R_T and the number of scale divisions a_T corresponding to the pointer deflection caused by the switching-in of the calibrating resistor it is possible to determine the value of the scale division C in resistance units:

$$C_s = \frac{\Delta R_T}{a_T} \text{ ohm/div.} \tag{1}$$

The value of a scale division in units of relative strain is:

$$C_\varepsilon = \frac{1}{S_s} = \frac{1}{2R\eta} C_s, \tag{2}$$

where R is the resistance of a single operative transducer, η is the strain sensitivity of the transducer.

The value of magnetostriction λ is calculated from the formula

$$\lambda = C_\varepsilon \alpha, \tag{3}$$

where α is the reading of the instrument in relative strain units.

A moving coil instrument connected to the output of the amplifier is convenient only for static magnetostriction measurements. If the sample is vibrating due to magnetostriction the instrument will only indicate mean values of the dynamic magnetostriction, therefore in order to obtain true curves of the sample variations it is necessary to feed the output voltage to an oscillograph on whose screen these curves can be observed and photographed.

The oscillograph is calibrated also by means of the calibrating resistor.

The measurement of dynamic magnetostriction amounts to the following. The sample with the transducers is mounted on a wooden plate and placed inside the magnetizing coil, which has two windings for permanent and alternating magnetic fields. After switching in the oscillator, amplifier and the oscillograph the oscillator is tuned to the required frequency and the bridge is balanced, by adjusting potentiometers P_1 and P_2 and the variable capacitor C (see Fig. 1). The bridge is balanced to obtain the minimum amplitude indication on the screen of the oscillograph, which corresponds to the unbalance voltage across the bridge diagonal. Next by connecting the dc and ac currents to the magnetizing coil and obtaining magnetostriction vibrations the required gain and conditions of oscillation are selected.

Having set the circuit as described above, the calibrating resistor is connected or disconnected and the difference in the amplitude of the fundamental is noted on the oscillograph screen. The calibrating resistor is switched in periodically during measurements in order to check the stability of the circuit as a whole. If owing to the effect of any causes the calibration changes, the gain should be readjusted in order to being it back to the original value.

Figure 3 shows the curves of dynamic magnetostriction and the magnetizing field, obtained by means of the above measuring set and a double beam oscillograph.

If all the measuring operations suggested in the article are carefully carried out this technique will provide an error of the order of ± 5%.

UFM-1 SET FOR TESTING MAGNETIC MATERIALS

L. S. Levin and E. N. Chechurina

The D. I. Mendeleev All-Union Metrological Scientific Research Institute developed a universal test set UFM-1 which provides characteristics of magnetic materials with combination magnetization in the range of 50 to 2500 cps both for single ring samples and for samples consisting of single and three-phase cores of magnetic amplifiers.

Since magnetic characteristics in conditions of complex magnetization depend to a considerable extent on the waveform of the alternating components, two limiting conditions for determining the characteristics are provided in the set: with a sinusoidal magnetic field strength ($H_{\sim} = H_{max} \sin \omega t$) or a sinusoidal induction ($B_{\sim} = B_{max} \sin \omega t$).

In the first instance control rheostats are connected in series with the ac circuit making the resistance of the circuit considerably larger than its inductance ($R \gg \omega L$). In the second instance the set is fed directly from a current transformer incorporated in the control device.

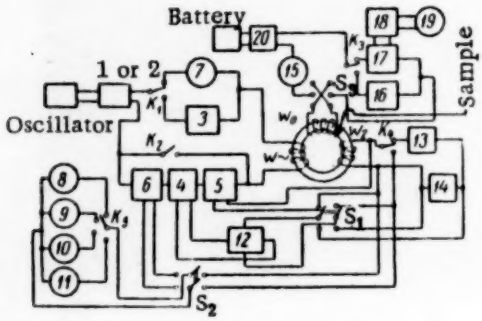

Fig. 1.

The controlling device consists of an autotransformer connected to the primary of a current transformer whose secondary is sectionalized with its maximum resistance not exceeding 0.06 ohms and an inductance of 0.004 h. When the sample under test is connected through a transformer to the controlling device the reactance of the circuit will be much larger than the resistance ($\omega L \gg R$) which is required for the sinusoidal magnetic induction condition.

In addition to the conditions of sinusoidal field strength and sinusoidal magnetic induction the set provides measurements with distorted current and induced emf waveforms. In the latter case in order to have consistent results it is necessary to indicate the ac circuit parameters (resistances and reactances) at which the measurements were made. For this purpose the real and imaginary parts of each component impedance in the circuit are measured in advance.

Figure 1 shows the schematic of the set version for a single sample. The ac circuit of the set consists of controlling device 1 or 2, the primary of the current transformer 3 type TT-2 carrying 0.1 to 50 amp, the magnetizing winding of the sample $W_{\sim}$, a set of resistances 4, a thermal wattmeter 5, and the primary winding of one of the mutual inductance coils 6. The mutual inductance coils ($M_1 = 0.1$ h, $M_2 = 0.01$ h, and $M_3 = 0.001$h) serve to determine the sum of the magnetizing current amplitudes by measuring the mean value of the emf induced in the secondary winding of the coil.

By integrating the instantaneous value of the emf $e = -M di/dt$ over half a period we obtain

$$E_{av} = \frac{2}{T}\int_0^{\frac{T}{2}} \left(-M\frac{di}{dt}\right)dt = 2fM(i_{max} + i_{min}). \qquad (1)$$

where E_{av} is the mean value of the emf induced in the secondary winding of the mutual inductance coil, in volts,

f is the magnetizing current frequency, cps.
M is the mutual inductance coefficient, h.

The effective values of the magnetizing current below 30 ma are measured on a thermocouple milliammeter 7 type T13.

The set provides for measuring the emf induced in the secondary windings of the mutual inductance coils and in the measuring winding of the sample by means of voltmeters of various types.

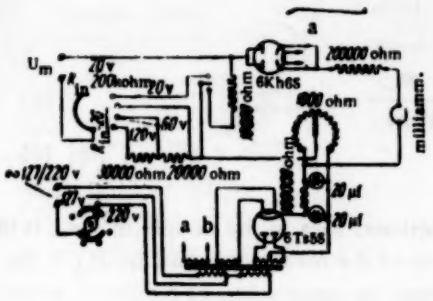

Fig. 2.

For measuring mean values of distorted voltages at 50 cps, voltmeter 8 with a movement type LM-1 and a mechanical rectifier is used. By its main error classification the voltmeter is grade 1.5; moreover when mean voltages are measured with a form factor exceeding 1.11 the error of measurement still does not exceed 1.5%.

For measuring mean values of distorted voltages in the range from dc to 2500 cps tube voltmeter 9 is provided whose schematic is given in Fig. 2. This voltmeter grade is 1.5 in the range of 50 to 2500 cps. In the range of 2500 to 5000 cps the voltmeter error increases to 2%.

For measuring effective voltages thermocouple voltmeter 10 is used. Main error classification in the range of 50 to 2500 cps makes it a grade 1.5 instrument; moreover it has a sufficiently high resistance (100 ohms/v) to be connected to the measuring winding without changing the conditions of magnetization of the sample.

Voltmeters 8, 9 and 10 differ to a certain extent from those normally produced since they were designed to measure distorted voltages in testing magnetic materials.

The set also has voltmeter 11 type LV9-2 for measuring sinusoidal voltages.

Oscillograph 12 type EO-7 included in the set provides the possibility of observing the shape of currents and emf's induced in the measuring winding of the sample and the secondary windings of the mutual induction coils. In addition the integrating circuit consisting of resistor 13 and a set of capacitors 14 permits one to observe hysteresis loops on the screen of the cathode-ray oscillograph. In the latter case the horizontal amplifier of the oscillograph is fed by the potential drop in resistor 4 which is connected in series with the magnetizing current circuit.

By means of the instruments described above it is possible to measure large permeability materials with an alternating current. Since the set is designed to measure not only with alternating current but mainly with simultaneous magnetization by alternating and direct currents, it includes a direct current circuit. When measuring single samples choke coil 16 is connected in series with ammeter 15 type M104/1 in order to limit alternating currents and emf's induced in the dc magnetizing winding. When a magnetic amplifier with any type of winding is tested, choke is replaced by resistor 17 of 1 ohm and the potential drop across it is fed to the filter with amplifier 18. By measuring the voltage at the output of the filter with voltmeter 19 type LV9-2 the effective value of the current second harmonic flowing in the control circuit can be determined for any given magnetic amplifier circuit.

Controlling device 20 serves to adjust the current of the magnetizing winding W_e.

Let us briefly examine the basic types of magnetic material characteristics which it is possible to determine by means of set UFM-1.

In practice when studying the behavior of materials in conditions of complex magnetization two types of permeability are mostly used in calculating magnetic amplifiers: the mean permeability of a frequently recurring cycle (μ_Δ) and the "effective" permeability (μ_e). These permeabilities can be represented by formulas

$$\mu_\Delta = \frac{B_{max} + B_{min}}{H_{max} + H_{min}} = \frac{B_\Delta}{H_\Delta}, \tag{2}$$

$$\mu_e = \frac{E_e}{I_e} K, \tag{3}$$

where B_{max} and H_{max} are the maximum magnetic induction and field strength respectively, B_{min} and H_{min} are the minimum magnetic induction and field strength respectively, E_e is the effective induced emf in the measuring winding of the sample, I_e is the effective magnetizing current, k is the coefficient depending on the geometrical dimensions of the sample, the number of turns and the frequency of the magnetizing current.

The sum of the amplitudes of the magnetic field strength H_Δ and the magnetic induction B_Δ can be determined by measuring the mean emf's E_{zav} at the secondary windings of the sample and the mean emf E_{av} at the

mutual induction coil.

$$H_{\Delta} = \frac{w_{\sim}(I_{max}+I_{min})}{l_{av}} = \frac{E_{av}\, w_{\sim}}{2fMl_{av}}, \quad (4)$$

$$B_{\Delta} = \frac{E_{2\,av}}{2fSw_2}, \quad (5)$$

where l_{av} is the mean length of the magnetic path, m, S is the cross sectional area of the sample, m^2, $w_{\sim}$ is the number of turns of the magnetizing ac winding, w_2 is the number of turns of the measuring winding, H_{Δ} is the sum of the field strength amplitudes, amp/m, B_{Δ} is the sum of the alternating components of magnetic induction amplitudes, webers/m^2.

In complex magnetization by alternating and direct fields, in a general case $B_{max} \neq B_{min}$ and $H_{max} \neq H_{min}$ since the curves can be asymmetrical with respect to the time axis due to the presence of even harmonics. Hence, having measured the mean emf's it is better to calculate directly the sum of amplitudes B_{Δ} and H_{Δ}. Only in the case of symmetrical curves is it permissible to divide the values of B_{Δ} and H_{Δ} by 2 and from that obtain the values of B_{max} and H_{max}.

The "effective" permeability is calculated from the values obtained by measurement on set UFM-1 and formula (3) which can be expanded as follows

$$\mu_e = \frac{l_{av}}{2\pi f S w_{\sim} w_2} \cdot \frac{E_e}{I_e}. \quad (6)$$

Permeability calculated from (6) is nominal and identical with μ_{Δ} when the magnetic induction and field strength are sinusoidal and represent the ratio B_{max}/H_{max}. It does not correspond to the standard effective permeability $\mu'_e = B_e/H_e$, but it is normally used in practice since the effective value of B_e is difficult to determine.*

Quantity μ_e is used in particular when the devices are calculated on the basis of effective current and voltage values (for instance voltage stabilizers, regulating chokes, etc).

Permeabilities μ and μ_e can be determined with respect to the alternating component of the magnetic field strength (or induction) or with respect to a direct field strength H_0. In the first instance field strength H_0 is kept constant and in the second it is advisable to keep constant the amplitude of the quantity which during measurements remains sinusoidal. For instance if measurements are made with a sinusoidal field strength then it is the field strength which is kept constant.

Set UFM-1 provides the following family of curves:

1) $\mu_{\Delta} = f(H_{\Delta})$ or $\mu_{\Delta} = f(B_{\Delta})$ at $H_0 = \text{const}$;

2) $\mu_e = f(H_{e_m})$ or $\mu_e = f(B_{e_m})$ at $H_0 = \text{const}$;

$$B_{e_m} = \frac{E_e}{4K_f S w_2} = \frac{E_e}{\pi\sqrt{2}\, f S w_2},$$

K_f is the form factor for sine wave: $K_f = \pi/2\sqrt{2}$

$$H_{e_m} = \frac{\sqrt{2}\, I_e w_{\sim}}{l_{av}}; \quad \mu_e = \frac{B_{e_m}}{H_{e_m}};$$

3) $\mu_{\Delta} = f(H_0)$ at $H_{\sim} = H_{max} \sin \omega t$ and $H_{max} = \text{const}$.

*$B_e = \sqrt{B_1^2 + B_2^2 + B_3^2 + \ldots + B_n^2}$ where B_1, B_2, B_3 ... B_n are the effective values of the fundamental and higher harmonic magnetic inductions. These values can be determined by means of a harmonic analyzer from the effective values of harmonic emf's induced in the measuring winding of the sample. Such a method of determining B_e is rather complicated and permeability μ'_e is not used in practice but is replaced by the nominal permeability μ_e.

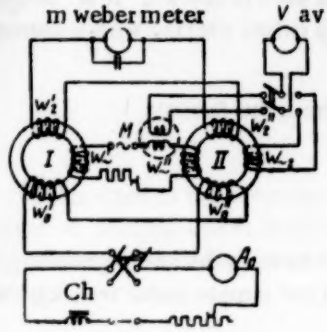

Fig. 3.

or at $B_\sim = B_{max} \sin \omega t$ and B_{max} = const; 4) $\mu_e = f(H_0)$ at $H_\sim = H_{max} \sin \omega t$ and H_{max} = const, or at $B_\sim = B_{max} \sin \omega t$ and B_{max} = const.

The first two types of families can be determined both for the condition of sinusoidal field strength and sinusoidal induction.

The direct field intensity is calculated in all instances from the formula

$$H_0 = \frac{w_0 I_0}{l_{av}}, \qquad (7)$$

where I_0 is the direct current intensity, amp, w_0 is the number of turns of the dc magnetizing winding.

Besides the above family of curves one is more and more often required to know additional characteristics specific for magnetization by direct and alternating fields. Such characteristics include, for instance, the relation between direct components of magnetic induction and field strength at various values of the alternating field strength, i.e., curves of the form of $B_0 = f(H_0)$, which are required for the solution of problems connected with transients in magnetic amplifiers. The theoretical methods of obtaining these curves [3] cannot always be considered satisfactory, since they do not take into account hysteresis phenomena or the different conditions of magnetization.

The methods of measuring the direct component of magnetic induction described in [4] refer to the case of small alternating components of induction.

In set UFM-1 a balanced method of connecting windings of two identical samples is used (Fig. 3). This circuit provides measurements over a wide range both of the direct and alternating component of magnetic induction and is in fact a magnetic amplifier circuit with series-connected ac windings.

Curves $B_0 = f(H_0)$ are plotted from the readings of the milliwebermeter taken at various values of the energizing dc.

The direct field strength is calculated from the value of the direct current by means of formula (7).

The direct component of the magnetic induction B_0 can be calculated from formula

$$B_0 = \frac{C\alpha 10^{-3}}{2w_{0_2}(S' + S'')}, \qquad (8)$$

where C is the milliwebermeter calibration, mwebers/division, α the instrument deflection when the direct current is switched (in divisions); S' and S", cross section areas of samples, m^2, w_{02} is the number of turns in the dc measuring winding.

Set UFM-1 provides data from plotting curves $B_0 = f(H_0)$ both for the condition of a sinusoidal alternating component of magnetic induction and for that of a sinusoidal field strength.

Since in the design of the set it was aimed at taking not only characteristics of single samples but of complete magnetic amplifier cores, its circuit provides the possibility of measuring the second harmonic of the current flowing through the control circuit of any magnetic amplifier.

The effective value of the current second harmonic can be calculated from the formula

$$I_{2f} = \frac{U}{K_y R_0}, \qquad (9)$$

where U is voltage measured by voltmeter 19 type LV9-2 at the output of filter 18 (Fig. 1); A is the gain of the amplifier; R_0 is the resistor 17 (Fig. 1) which is in the direct current circuit and is connected to the filter with the amplifier.

Important characteristics apart from those already mentioned include the hysteresis and eddy current losses both in the case of ac and mixed ac and dc magnetization. For measuring losses a thermocouple wattmeter 5

(Fig. 1) developed by members of the VNIIM D. I. Zorin and A. Ia. Vezikovich is used in the set. It is designed to measure power in circuits with a small cos φ and has a range of 0.1 to 2000 amp (when working with a current transformer) with an error not exceeding ± 1.5% in a range of 50 to 2500 cps.

The calculation of relative hysteresis and eddy current losses is carried out from the formula

$$P_{he} = \frac{1}{m}\left(P_w \frac{w_-}{w_2} - \frac{U^2}{r_2'}\right)\left(1+\frac{r_2}{r_2'}\right), \qquad (10)$$

where P_W are the losses read on the thermocouple wattmeter, w; w the number of turns in the ac magnetizing winding; w_2 is the number of turns in the ac measuring winding; m is the mass of the sample under test, kg; and U is the reading of the voltmeter with a T13 movement, v,

$$r_2' = \frac{r_v r_w}{r_v + r_w},$$

where r_V is the voltmeter resistance, ohms; r_W is the wattmeter circuit resistance, ohms; and r_2 is the measuring winding resistance, ohms.

The value of magnetic induction corresponding to the measured losses is calculated from the formula

$$B_{max} = \frac{E_{2\,av}}{4fSw_2}.$$

SUMMARY

Above set is designed for investigating magnetic characteristics of materials working in conditions of mixed magnetization which is often the case in many instruments and automatic devices.

Tests have shown that errors in permeability values obtained by means of this set from formulas (2) and (3) in the range of 50 to 2500 cps do not exceed ± 5% and the error in measuring hysteresis and eddy current losses in the same range does not exceed ± 4%.

The error in determining the direct component of magnetic induction can reach 8 to 10% due to the considerable errors of reading of the milliwebermeter in the presence of an alternating magnetizing field.

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LOW-FREQUENCY WIDE-BAND RC FILTER

V. S. Chaman

In some of the electronic amplifiers used in measurement techniques it becomes necessary to suppress as much as possible one or more frequency components of the amplified voltage. We can quote as an example the amplifier for an induction small-displacements gauge described in our article (Measurement Techniques, No. 2, 1956).

In this instance a precise zero balance of the bridge was required at the fundamental frequency; hence some of the harmonics had to be carefully filtered out: either the first two harmonics, i.e., the 2nd and the 3rd, or the first two odd harmonics, i.e., the 3rd and the 5th.

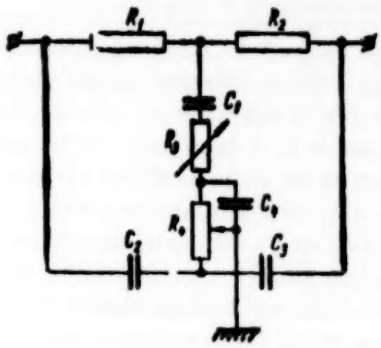

Fig. 1.

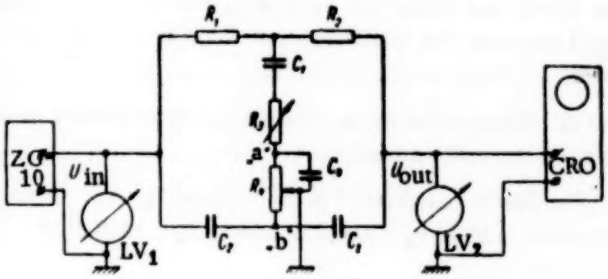

Fig. 2.

kilohms ± 10	kilohms	kilohms	μf ± 10%	μf ± 10%	μf ± 10%	f_{min} to f_{max}, cps
460	300	1	0.1	0.1	4	40–800
460	400	1	0.05	0.05	4	80–1000
100	70	1	0.05	0.05	2	170–4000
27	18	1	0.05	0.05	0.1	320–1600
27	18	1	0.015	0.015	0.05	1000–5000

In order to suppress these harmonics, above circuit included two normal RC bridge filters for 100 and 150 cps with appropriately selected elements. Experience of RC filter construction shows that their tuning must be very accurate to suppress reliably the unwanted frequencies since the ratio of the balanced-out voltage to the unbalanced harmonic can be of the order of 0.05 and smaller.

With normal RC bridge filter circuits the accuracy of tuning to quasi-resonance required in order to obtain maximum supression of the unwanted frequency leads to manufacturing difficulties. In fact, so as to obtain a satisfactory accuracy of tuning, the values of resistors and capacitors comprising the filter should not deviate from their nominal values by more than ± 1%.

Self-balancing bridge circuits with an induction transducer described in the above mentioned article were used in devices for controlling cylinder-and-cone grinding machines (instrument BV-962 and others). In this connection it became necessary to make the tuning circuits used by them simpler and cheaper to make.

One of the methods of overcoming these difficulties would be to provide continuous tuning for both RC filters over a certain frequency range. For tuning an RC filter, however, it is required to vary at least three of its elements, for instance, three resistances. Obviously such a filter could not be made of standard components and the production by handicraft methods of variable resistors would both complicate and make more expensive the construction of the instrument.

For these reasons the Replacements Bureau's Electrical Automation Laboratory of the Committee for Standards, Measures and Measuring Instruments developed a new type of RC filters with a simple method of continuous tuning over a wide band of frequencies, which do not require a precise selection of component parts.

Figure 1 shows the schematic of the new adjustable RC filter, which differs from the normal twin T filter

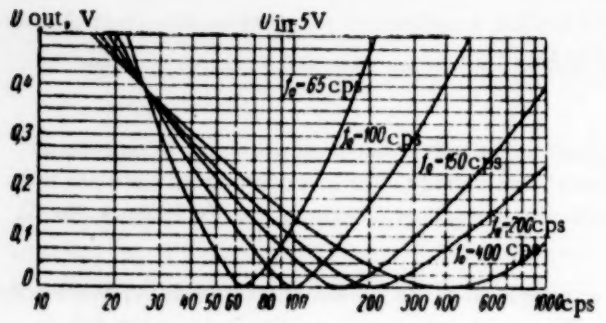

Fig. 3.

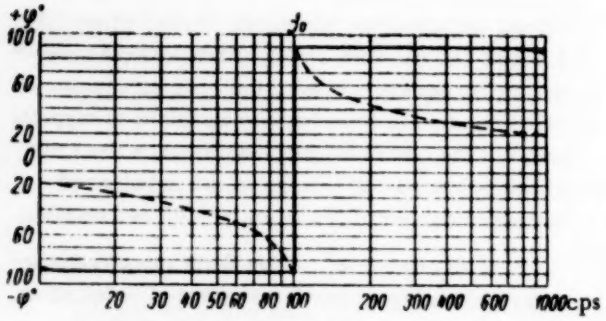

Fig. 4.

mainly by the fact that the ground connection is not taken to the junction point of the two T filters but to the contact of a potentiometer used as a resistance in the vertical arm of the low-pass T filter.

In order to obtain maximum attenuation at the quasi-resonance frequency with large deviations (up to 15 to 20%) from the nominal values of the filter components (R_1, R_2, C_1, C_2, C_3 and C_4) an adjustable resistor R_3 is connected in series with capacitor C_1 in the vertical arm of the high-pass T filter. This resistor can, of course, be changed for an accurately selected fixed resistor since it does not affect the tuning of the circuit.

We adopted the following procedure for adjusting new filters. For this purpose the circuit shown in Fig. 2 was made up. Having moved potentiometer R_4 slide to point "a" we adjusted the frequency of the audio-oscillator AO and the variable resistance R_3 until oscilloscope CRO (or a tube voltmeter) indicated a complete disappearance of the fundamental frequency voltage fed to the input of the filter. The oscilloscope showed that only higher harmonics of the quasi-resonance voltage remained at the output of the filter. Following this operation we fixed the slide of the variable resistor R_3 in its position or soldered in its place a fixed resistor of the same value, and found that by moving the slide of potentiometer R_4 away from point "a" towards point "b" we changed smoothly the quasi-resonant frequency of the filter keeping the voltage at that frequency completely suppressed.

The values of resistors and capacitors for a number of RC filters made by us, as well as the frequency ranges covered by their maximum attenuation frequencies are given in the table attached.

Figure 3 shows experimentally obtained curves for five different positions of potentiometer R_4 slide for an RC filter with the following components: $R_1 = R_2 = 230{,}000$ ohms $\pm 10\%$; $R_3 = 130{,}000$ ohms; $R_4 = 1000$ ohms; $C_1 = 0.1\ \mu f \pm 10\%$; $C_2 = C_3 = 0.1\ \mu f \pm 10\%$; $C_4 = 2\ \mu f$.

It will be seen from above curves that as the quasi-resonance frequency is increased the attenuation of the frequencies passed by the filter also rises. When two or more filters are required in the circuit they can all be made exactly the same and then tuned to the required frequencies, or each filter can be designed separately striving to make the required resonant frequencies the lowest frequencies in each filter band; in the first instance we shall gain in simplicity of manufacture and tuning of the circuit and in the second we shall be able to use an amplifier with a lower gain.

Figure 4 shows an experimentally obtained phase characteristic of the new RC filter. It differs considerably from the same characteristic of conventional RC filters shown by a dotted line. It would appear from the shape of the new filters' characteristic that their use in frequency-sensitive negative feedback circuits of low-frequency tuned amplifiers will be difficult.

Experience has shown, by the way, that the resonance and phase characteristics of these filters depends but little on the input and output terminating impedances, at least in the range from 30,000-50,000 ohms to infinity (open circuit).

In order to obtain a smoother variation of the quasi-resonance curve with respect to the angle of rotation of the potentiometer R_4 knob, when the slider travels from point "a" to point "b", the potentiometer should be logarithmic.

POTENTIAL DIVIDERS BASED ON THE SUMMATION OF CURRENTS PRINCIPLE

K. A. Netrebenko

Let us examine the circuit shown in Fig. 1. It consists of two busbars to which the input voltage is applied, an adding star-shaped system of resistances and a system of switches. Let the value of the resistances forming the star satisfy the equation

$$r_{12}=r_{13}=2r_{11};\ r_{14}=4r_{11};\ r_{24}=10r_{14};\ r_{34}=100r_{14},\ r_0=400r_{11}, \quad (1)$$

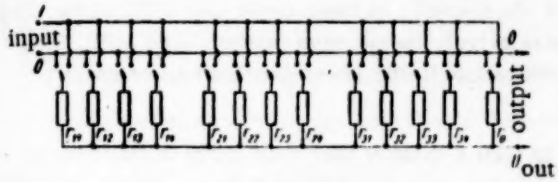

Fig. 1.

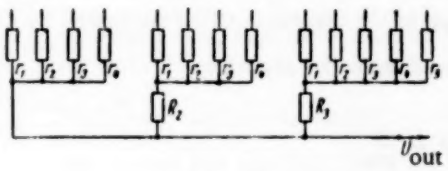

Fig. 2.

i.e., let the conductances be proportional to numbers 4, 2, 2, 1; 0.4, 0.2, 0.2, 0.1; etc. If the potential of one of the busbars be taken as 0 and the potential of the other as 1, the voltage between the zero busbar and the apex of the star U_{out} will be

$$U_{out}=0.4x_{11}+0.2x_{12}+0.2x_{13}+0.1x_{14}+0.04x_{21}+\ldots+0.001x_{34}+0.001x_0. \quad (2)$$

where $x_k = 0$ if the corresponding conductances are connected to the zero busbar, $x_k = 1$ if the corresponding conductances are connected to busbar 1.

Thus, the system represented in Fig. 1 is a three decade potential divider with a binary-decimal scale. Its output voltage can be varied between 0,000 and 1.000 in steps of 0.001. Potential dividers with any number of decades can be constructed on the basis of this principle.

It should be noted that contrary to a number of other circuits with adding currents the above circuit is represented by an equation of the form of (2) accurately and not approximately. This equation is obtained from (1) and Kirchhoff's first law as applied to the apex of the triangle:

$$\sum_{\kappa}\frac{x_\kappa-U_{out}}{r_\kappa}=0. \quad (3)$$

In order to reduce the output voltages (more accurately to adjust the potential divider's transfer constant) by a ratio of n it is sufficient to connect across the output terminals resistor r_{00} of the value of

$$r_{00}=\frac{r_0}{(n-1)\cdot 10^m}, \quad (4)$$

where m is the number of decades.

The proposed potential divider circuit has a number of advantages as compared with the conventional circuits.

A conventional multidecade divider with double or shunted decades has on the average 10 to 20 resistors per decade.

The output resistance of conventional dividers changes with the setting of the divider. In the above circuit the output resistance is not affected by the setting. It is possible, therefore, without a reduction in accuracy to use these dividers with a considerable current consumption in the output load circuit (at a fixed load).

Valuable advantages of the proposed circuit consist in the relative simplicity of switching and the possibility of using lower quality contacts. These characteristics are especially useful for designing various automatic

circuits, since they provide the possibility of switching precision dividers by means of electromechanical relays, and, in certain conditions even by means of noncontact electronic or semiconductor switching.

Such a divider was used for instance, by the author in a digital automatic potentiometer which he had previously designed [1]. The use of this divider provided a considerable simplification and reduction in cost of the instrument's production and increased its reliability.

Among the disadvantages of the above circuit an inconstant input resistance and large resistances in the lower ranges of the multidecade instruments should be mentioned. Thus,if the smallest resistor in a four decade divider is 1 kilohm the largest one should be 4 meg.

The input resistance can be made constant if necessary by connecting ballast resistances between the input busbars. When the divider setting is changed the ballast system is switched in such a manner that the conductance between the input busbars remains constant.

The high resistance of the lower order decades does not in the majority of cases cause any difficulties. High precision in this instance is not required and it is possible to use relatively inexpensive resistors type MPT, manganin resistors or even nonwire-wound resistors. Moreover the resistances in the lower decades can be greatly reduced by the method shown in Fig. 2.

The set of resistors shown in Fig. 2 is divided into groups in such a manner that each group is made up of four relatively low resistors proportional to numbers 1, 2, 2 and 4 and a series multiplier resistor. This multiplier resistor (Fig. 2) is calculated in such a way that the total conductance of the group between the output terminal and the bunched ends of resistors connected to the switches is equal to the equivalent resistance in the circuit of Fig. 1. It is easily seen that under these conditions the output voltage of the circuit is still determined by Eq. (2).

The parameters of the actual circuit shown in Fig. 2 are obtained from the equation

$$r_1=\frac{1}{4}\,r_4;\ r_2=r_3=\frac{1}{2}\,r_4;\ r_5=r_4=\frac{1}{100}r_0;$$
$$R_3=\left(\frac{10}{9}-\frac{1}{9}\right)r_4=r_4;$$
$$R_2=\left(\frac{100}{10}-\frac{1}{10}\right)r_4=9.9\,r_4. \qquad (5)$$

Thus,the decade which should have contained resistances of 1, 2, 2, 4 and 4 meg is replaced by a group comprising only one high resistance of about 0.4 meg. Other methods of separating into groups are also possible.

Apart from the code 4, 2, 2, 1, used in the above circuits, other binary-decimal codes as well as purely binary codes can be used.

It is also possible to construct according to above principles dividers made up of reactive elements (for instance capacity dividers for ac voltages).

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TESTING THREE PHASE SETS USED FOR THE CALIBRATION OF ELECTRICITY METERS

I. N. Osher

Often different results are obtained when checking electricity meters on different test sets. This is particularly noticeable with reactive meters. The reason for the discrepancies is often due to the defects in the testing equipment.

There exist no specifications approved by the Committee for Standards, Measures and Measuring Instruments for three-phase electricity meter testing equipment. In order to make the testing of industrial electricity meters uniform the Committee's VNII drew up specifications for three-phase test sets.

Below we give the specification and testing technique for the sets.

I. Conditions of testing. Sets should only be tested if the following conditions are observed:

1. A schematic circuit should be attached to the equipment and there should be no discrepancies between it and the wiring of the equipment.

2. The wires and components should be securely fixed.

3. Load variations as read on wattmeters should not exceed one division in the upper half of a 150 division scale.

II. Equipment and testing specifications.

1. The circuit and construction of the equipment should be such that setting up of the required load could be made easily and simply.

2. The equipment should have a check ammeter of a grade not lower than 2.5 and a voltmeter of a grade not lower than 1.5 for each phase. They should be numbered from left to right in the order of phases.

3. The voltmeters should have the facility of measuring both the phase and line voltage; the first voltmeter from the right should read the voltage of the first phase and when switched the voltage between the first and second phase; the second voltmeter should read that of the second phase and between the second and third phase; and finally the third voltameter should read the voltage of the third phase and that between the third and first phases.

4. The ranges of the measuring instruments should correspond to the required limits of measurement over the whole range of testing.

5. All the switches, keys and terminals of the equipment should have clear and durable marking.

6. Electricity meters under test should be suspended from the devices provided in the set in their normal operating position.

7. The phases of the set in current and voltage circuits should follow each other in their right order; their order should be checked by means of a phase indicator.

8. When the phase-shifting transformer drive is rotated in the clockwise direction (from the $\cos\varphi = 1$ position), an inductive phase shift should be produced in the tested meters.

9. Changes in the secondary voltage produced by turning the phase-shift transformer rotor should not exceed 1.5%. The device is checked by means of two voltmeters connected to the primary and secondary terminals of the phase-shift transformer. The variations of the secondary voltage noticeable during the turning of the rotor should not be taken into account.

10. The adjustment of the current in one of the phases should not affect that of the other two phases. The checking is carried out by means of the ammeters and current transformers mounted on the set for all the ranges to be tested.

11. The adjustment of current, phase shift or voltage should be smooth and should provide the setting of any required point on the scales of the standard ammeters, wattmeters and voltmeters, respectively.

12. The phase-shift transformer rotor should have a reliable brake, so that at full voltage load there should be no random variations of cos φ. The phase-shift transformer drive flywheel should turn freely.

13. The phase differences between the phase voltages and between phase currents should be 120°. This is checked by means of three standard wattmeters connected to measure phase voltages and phase currents (as for checking four conductor electricity power meters). At cos $\varphi = 1$ the wattmeters are set for equal readings at any point in the upper third of the scale, cos $\varphi = 1$ being set by means of one of the wattmeters. Next cos φ is changed from 1 to 0.5 m by means of the phase-shifting transformer. The differences in the wattmeter readings should not exceed 4 divisions out of a scale of 150.

14. All the electrical circuit contacts must be reliable. The contacts should be checked by inspection and mechanical operation.

15. The difference in voltage between the first and last voltage terminals should not exceed 0.1%. This should only be checked for large capacity sets capable of measuring dozens of meters or in the case of suspected defects in wiring.

The checking is done by means of measuring with a millivoltmeter the voltage drops in each of the leads connecting the first terminal with the last one in the strip. For this purpose the strip should be completely filled with meters with the smallest nominal voltages. A rectifier instrument, (for instance a tester) or a tube voltmeter with a sensitive enough scale can be used. Before connecting the millivoltmeter, a voltmeter should be used to make sure that both terminals are on the same lead.

16. There should be no pickup of external magnetic fields by the standard instruments mounted on the set, neither should the set equipment itself induce any fields in these instruments. The set is checked by comparing the readings of two wattmeters at the maximum current of the set and cos $\varphi = 1$. The wattmeters are connected to the same voltages, corresponding to their nominal voltages, and the same current is made to flow through both of them, but at first they are connected so that the current flows in the same direction through both of them and then one of them is reversed so that the currents become 180° out of phase.

17. The waveform must be practically sinusoidal even with the most unfavorable loading. This can be checked either visually on an oscilloscope screen or by means of a harmonic analyzer. In order to obtain the worst possible voltage waveform it is necessary to raise the voltage (or current) to the permissible maximum by means of the adjusting transformers. Any most convenient voltage or current limit of the meter under test can be chosen. The worst waveform is obtained in the phase voltage. The current waveform can be conveniently checked by connecting a current transformer to the minimum nominal current (0.5 amp) and feeding the voltage from the secondary of this transformer to an oscilloscope.

18. The insulation of the current carrying components of the set must withstand, with respect to the metal uninsulated parts of the set, a sinusoidal voltage of 1500 v at 50 cps for one minute. The insulation between the current and the voltage circuits of the set must withstand the same test. When the insulation is tested the standard instruments should be disconnected. If there are links between the voltage and current circuits in the set they should be disconnected before testing insulation between them.

19. The standard current transformers mounted in the set should be of grade 0.2 and have a nominal load of 0.4 ohm.

20. The loading of the standard instruments' current transformers must not exceed the nominal figure or be less than the minimum load for which the error of these transformers is known. The actual load of the current transformers is measured by means of the voltmeter and ammeter method. The resistance of the current transformer load is measured as the ratio of the voltage across the secondary of the transformer and the current flowing in the secondary circuit which produced that voltage. This measurement should be made at a current 50 to 100% of the nominal value. For measuring the voltage at the secondary terminals of the transformer a rectifier meter (for instance a tester) may be used.

21. If the set contains a switch for changing the wattmeter connections' circuit the switch inscriptions should correspond to the circuit. In order to check this point a standard wattmeter should be connected to the

terminals allocated for the electricity meters under test in a manner corresponding to the circuit diagram of that switch position and the reading of the standard and set wattmeters compared. Wattmeter readings are compared at current loads of at least 50% of the nominal value of $\cos\varphi = 1$ and $\cos\varphi = 0.5$ for active power meters and at $\sin\varphi = 1$ and $\sin\varphi = 0.5$ for reactive power meters.

CERTAIN PROBLEMS OF ELECTRICAL POWER METERING

E. K. Balashov, A. M. Iliukovich and A. L. Shargorodskii

GOST 6570-53 for single phase electricity power meters specifies permissible errors for loads above 5% of the rated value. The behavior of meters at loads below 5% of the rated value is not covered by a specification, although in lighting circuits, meters often work under such conditions. The table gives the loading of differently rated meters in percentage of the rated value loaded by incandescent lamps of different nominal values (according to GOST 2239-54). Loads lying in the region below 5% of the rated value are enclosed in a frame. It will be seen from the table that in many cases, when loaded by incandescent lamps, meters may work at loads below those covered by the specification. Such loads can be of long duration (for instance when dark passages are lit all day long, etc); the energy registered during this period may constitute a large proportion of that used by the consumer; it is, therefore, of interest to investigate the errors of modern meters operating with very small loads.

Meter rating \ Load, w		15	25	40	60	75	100
127 v. 5 amp	Meter loading, %	2.4	3.9	6.3	9.5	11.8	15.7
220 v. 5 amp		1.4	2.3	3.6	5.4	6.8	9.1
127 v. 10 amp		1.2	2.0	3.1	4.7	5.9	7.9
220 v. 10 amp		0.7	1.1	1.8	2.7	3.4	4.5

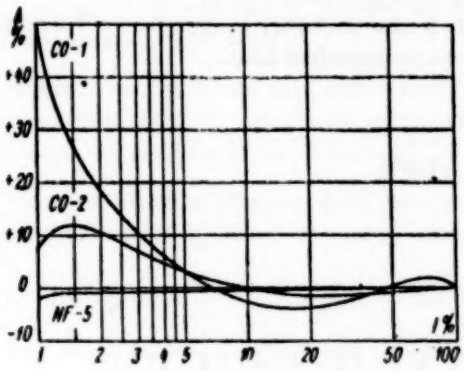

Fig. 1.

Figure 1 shows experimentally obtained load curves, drawn to a logarithmic scale, of some of the modern type electricity meters produced both at home (CO-1 and CO-2) and abroad (NF-5 meter of the Metropolitan-Vickers Co, Britain). The meters were normally adjusted and had approximately the same sensitivity. Inspection of these curves leads to the following conclusions.

1. Meter errors in the region of very small loads can be very large, introducing a considerable discrepancy in metering.

2. The meter error in the region of very small loads is obviously related to the general shape of the load curve. The larger the deviation of the load curve from a straight line in the region of the loads covered by specification (5 to 100% of the rated value), the greater will the error be at loads below 5% of the rated value.

The latter conclusion leads to the assumption that the shape of the meter load line in regions below the 5% loading is in the main due to the same reasons as that in the region of 5 to 20% loading, namely to the non-linear relation between the current and the operating magnetic flux in the series circuit [1]. Tests of several meters of the same type confirmed the assumption that the load curve in the region of very small loads is a typical characteristic of the meter, i.e., is peculiar to a given type of meter and depends but little on the accidental differences in assembly. Changes in its shape from meter to meter are due in the main to the deviation of the

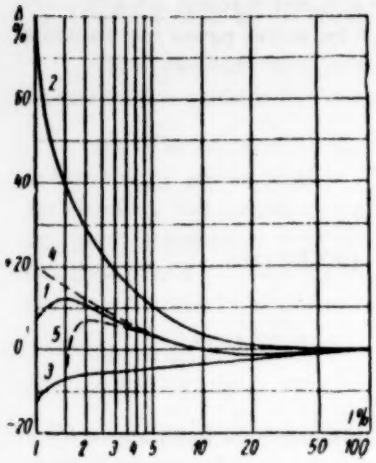

Fig. 2.

compensation adjustment from the mean value characteristic for the type of meter. This is illustrated in Fig. 2 where load curves of the same type CO-2 meter are shown with different adjustments made at 10% of the rated load. Curve 1 corresponds to normal adjustment at 10% of the rated load, curves 2 and 3 to setting at 10% of the rated load to errors of + 3.5 and − 3.5% respectively, i.e., to errors allowed by GOST 6570-53 for grade 2.5 meters. In all the three instances the meter was adjusted to the same sensitivity (about 1%). Inspection of curves in Fig. 2 shows that the quality of meter adjustment at 10% of the rated load affects considerably its behavior at loads below 5% of the rated value.

The shape of above curves is also affected by the sensitivity of the meter (curves 1, 4 and 5 in Fig. 2). Curve 1 represents a normal load curve of a type SO-2 meter at a sensitivity of the order of 1%, curve 4 corresponds to a sensitivity of 0.5% and curve 5 to that of 1.5%. The adjustment of the meter at 10% of the rated load was exactly the same in all the three instances.

On the basis of these tests the following conclusions can be drawn.

1. Under normal operating conditions single phase electricity meters often work during long periods at loads lower than 5% of the rated value; hence, it is necessary to check in qualifying tests of meter types to what extent the design of the meter provides a correct reading at that range of loading. Meter type SO-2 produced by our industry has unsatisfactory characteristics in the range of small loads; this should be taken into account when designing new types.

2. Improvement of meter accuracy in the region of loads lower than 5% of the rated value can be attained by a general improvement of the load curve in the region of loads 5 to 20% of the rated value, i.e., by decreasing the nonlinearity of the relation between current in the load and the effective flux in the series circuit.

3. When the GOST 6507-53 for ac electricity meters is revised it will be necessary according to international practice and operational requirements to take 5% and not 10% of the rated load as the minimum load for which operating conditions are specified for grade 2.5 meters. It is also necessary to introduce a 2.5 amp rating for meters and restrict the limits of permissible errors at the lowest specified load.

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CONNECTING SINGLE PHASE ELECTRICITY METERS FOR TESTING

A. M. Iliukovich and V. A. Vinogradov

For speeding up and facilitating the connection of electricity meters to test racks simple connecting shoes can be used (Fig. 1). Shoe 1 made of an insulating material is fixed by means of a meter terminal board screw which fits into slot 2 of the shoe. Spring contacts 2 are connected by means of flexible wires 4 to the corresponding terminals of the rack, the contacts press against the protruding heads of the meter terminals and the meter is thus connected to the test rack. Meters of various types not having the same spacing between terminals may have to be tested in inspection laboratories and repair shops. For such cases the above shoe should be made adjustable for various spacings.

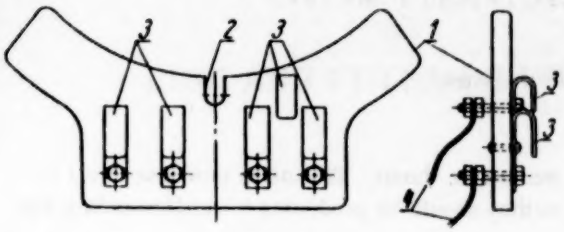

Fig. 1.

In meter manufacturing plants (for instance the Mytishchinsk electricity meter plant and the Leningrad electromechanical plant) more elaborate shoes are used (Fig. 2).

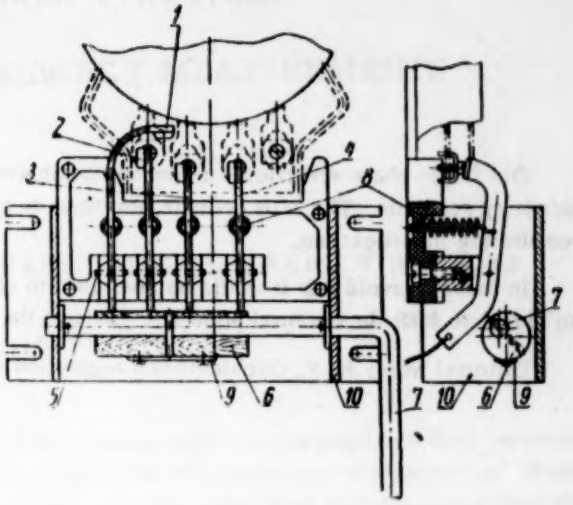

Fig. 2.

The meters are connected to the testing circuit by means of moving contacts 1, 2, 3 and 4, which can swivel about their axes 5 and are connected to the test rack with flexible leads.

The position of the moving contacts is controlled by means of an insulated eccentric rod 6 with a handle 7; the contacts are shown in an operated position, i.e., when the meter is connected for testing.

The required contact pressure is provided by springs 8. For disconnecting the meter the handle is turned through 90° making the eccentric rod swivel the contacts about their axis and thus disconnecting the meter from the test circuit. The current circuit of the test rack, however, is not disconnected since contacts 2 and 3 are shorted by plate 9.

All the shoe details are mounted on frame 10 fixed to the test rack.

A slightly different shoe is used by the Vilnius electricity meter plant. In this design the contacts connecting the meter to the test rack enter the meter fixing holes and press against the tightly screwed in fixing screws.

The use of semiautomatic connecting shoes considerably increases the productivity of labor in meter testing and avoids incorrect connections.

Great attention is also paid to this question abroad. In many instances devices similar to those described above are being used [1]. Semiautometic connecting devices similar to those used in our plants are also used in test racks designed for testing meters with different terminal spacings.

Good results were obtained from pneumatic contact drives [2]. Article [3] notes the great increase in labor productivity attained by using semiautomatic connecting devices.

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HECTOWATT-HOUR ELECTRICITY METERS

K. V. Ovchinnikov

Old single phase electricity meters are calibrated in hectowatt -hours. This often produces errors in electricity accounts. The bills become ten times as great as they should be producing misunderstanding and necessitating investigations.

In order to avoid this it would be advisable to change during current meter repairs the marking "hecto" into "kilo" to shift the decimal point one place to the left and to color one more digit window.

Editorial Note: K. V. Ovchinnikov's suggestion deserves consideration of the electricity supply organizations.

HIGH AND ULTRAHIGH FREQUENCY MEASUREMENTS

MAGNETIC DAMPING OF HIGH-FREQUENCY OSCILLOGRAPH VIBRATORS

B. A. Seliber

Vibrators constitute the most important component of any nonelectronic oscillograph and their parameters greatly influence the accuracy, sensitivity and speed of recording of the phenomena under observation. Normally the vibrator properties are characterized by two basic quantities: sensitivity and their self-resonance frequency in air. The latter quantity, however, only gives an approximate indication of the frequency range within which the vibrator can be used with the required degree of accuracy.

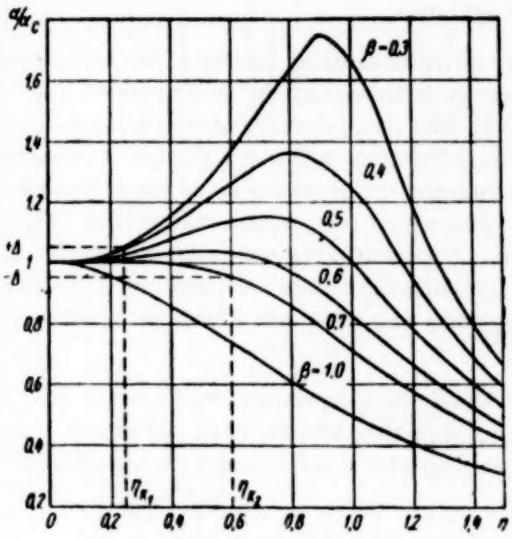

Fig. 1.

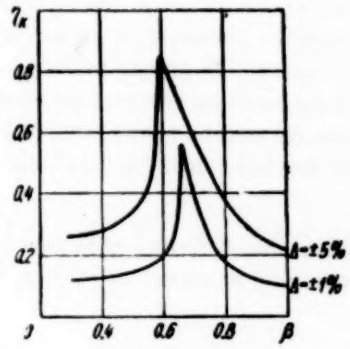

Fig. 2.

The reason for this uncertainty is due to the fact that all the high frequency vibrators (with a self-resonance frequency of 1000 cps upwards) use liquid damping, which greatly reduces their natural resonance frequency (to one half of that in air) by adding the mass of liquid, and makes it dependent both on the properties of the liquid and the design of the vibrator. The frequency bandwidth is also affected to a great extent by the degree of damping. It is known [1] that the amplitude-frequency characteristic of the vibrator can be expressed by the equation

$$\frac{\alpha'}{\alpha_c} = \frac{1}{\sqrt{(1-\eta^2)^2 + (2\beta\eta)^2}}, \qquad (1)$$

and represented by a family of curves (Fig. 1). Here α is the vibrator deflection at a given frequency, α_c the vibrator deflection on dc, β the degree of damping, and $\eta = f/f_0$ is the ratio of the recorded frequency to the natural resonance frequency of the vibrator; moreover with liquid damping f_0 should be taken as the natural resonant frequency without damping and corrected for the additional mass of the liquid.

It will be seen from Fig. 1 that, with a given recording error $\pm\Delta$, various damping values will correspond to certain values of the frequency range η_{k1} and η_{k2}.

The effect of the degree of damping on the frequency range can be shown even clearer if Eq. (1) is solved with respect to η

$$\eta_\kappa = \sqrt{1 - 2\beta^2 \pm \sqrt{(1-2\beta^2)^2 + \left(\frac{\alpha_c}{\alpha_c \pm \Delta}\right)^2 - 1}}; \qquad (2)$$

of all the values of η_k obtained for given values of Δ and β only the smallest should be taken.

Figure 2 represents the relation $\eta_k = f(\beta)$ at Δ equal to $\pm$ 1 and $\pm$ 5%. It will be seen from these curves

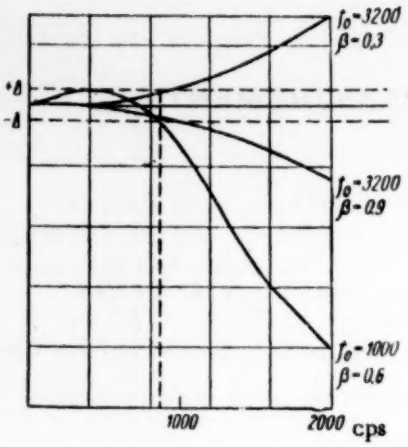

Fig. 3.

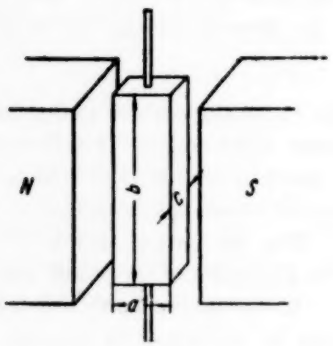

Fig. 4.

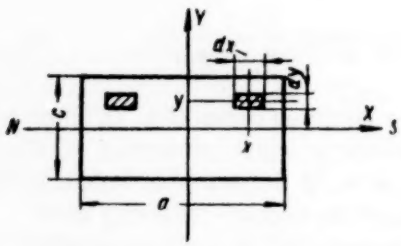

Fig. 5.

that the frequency range of the vibrator can change with the degree of damping by a factor of 3 to 4.

It should be stressed that the comparison of the frequency range alone is an insufficient criterion for comparing for frequency characteristics of vibrators. Figure 3 shows frequency characteristics of three vibrators: one with a natural resonance frequency of 1000 cps and degree of damping 0.6 and two vibrators with a natural resonance frequency of 3200 cps and degrees of damping of 0.3 and 0.9. Although in the limits of $\Delta = \pm 5\%$ the three vibrators have the same frequency range of about 850 cps at lower or higher frequencies, however, the latter two vibrators have a smaller error than the first one. This does not mean, however, that the vibrators with a natural resonance frequency of 3200 cps will always reproduce the observed processes better. For instance in recording a rectangular pulse the vibrator with a degree of damping of 0.3 will give an overshoot of about 40%.

All these facts show the great effect the degree of damping has on the frequency characteristics of vibrators. From this point of view the use of liquid damping in high frequency vibrators can only be regarded as a palliative.

The main defect of liquid damping consists in the dependence of viscosity on temperature in known liquids. When paraffin and glycerine liquids, widely used until recently, are employed the degree of damping changes by 40 to 50% with a change of temperature of 10°C. In such vibrators the frequency range was reduced to a third of its original value with a temperature change of ± 10°C from its nominal value. A great advance was made in 1949-50 when silicon-organic (polysiloxane)liquids were introduced, which in recent years are beginning also to be used widely by foreign firms.

Even with these liquids the temperature coefficient of the degree of damping is equal to 15 to 20% for 10°C, and liquids suitable for vibrator damping with a lower temperature coefficient are as yet unknown.

The second important defect of liquid damping is the practical impossibility under production conditions of determining accurately the degree of damping of each vibrator, so that the deviation from the optimum value may reach considerable dimensions and make the frequency range 2/3 or 1/2 of the theoretically possible. It would be expedient in making vibrators to control the degree of damping rather than the natural resonance frequency in air. It is, however, very difficult under production conditions to select a liquid with the required viscosity for each vibrator. In loop vibrators it is possible to change the degree of damping by adjusting the tension of the loop, (this will of course change the natural resonance frequency as well) but in practice this method cannot be used since it results in strains in the mirror.

We shall not dwell here on other defects of liquid damping, for instance the difficulty of hermetization, the effect of the liquid on the mirror, etc. Neither can the difficulty of applying frequency correction be overlooked [2].

It will be seen from the above that the use of liquid damping involves a number of substantial defects in the first instance the great difficultly in using the oscillograph at lower or higher temperatures than the nominal. Yet there still exists the opinion that liquid damping is inevitable in vibrators working at frequencies of 600 to 1000 cps or higher [3, 4, 5].

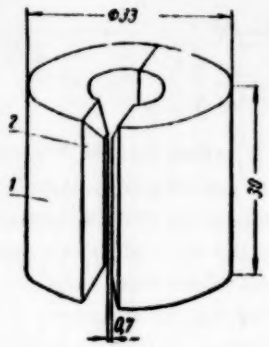

Fig. 6.

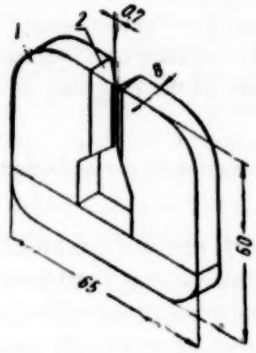

Fig. 7.

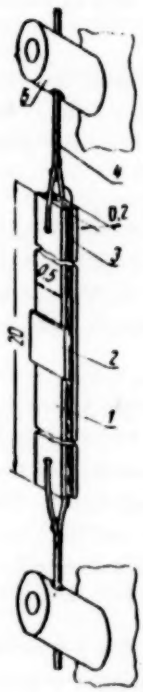

Fig. 8.

Let us now examine the limiting frequency of vibrators working with magnetic damping.

Let a metal plate of dimensions a, b and c be suspended in a magnetic field (Fig. 4). Let us find the value of the damping coefficient P_k of this plate, and for that purpose consider an elementary turn (Fig. 5) of cross-section dxdy with coordinates x and y.

$$P_{dxdy} = \frac{\Phi^2}{R}.$$

For $b \gg a$ and $b \gg c$ it is possible to write

$$P_{dxdy} = \frac{(2xbB)^2}{\frac{2b}{dxdy}\rho},$$

where Φ is the coupling flux with the elementary turn, R the resistance of the turn, B the induction, and ρ is the electrical resistivity. Hence,

$$P_K = \frac{2bB^2}{\rho}\int_0^{a/2}\int_{-c/2}^{+c/2} x^2\,dxdy = \frac{B^2a^3bc}{12\rho} \qquad (3)$$

We neglect here the interaction of currents flowing in the elementary turns, which in practice, with small dimensions of the plate, is quite permissible.

The moment of inertia of the plate is

$$J_K = \gamma abc\frac{a^2+c^2}{12}, \qquad (4)$$

where γ is the density of the plate material.

Substituting (3) and (4) into the well-known formula relating the frequency and the degree of damping

$$f = \frac{P}{4\pi J\beta},$$

we shall obtain, taking dimensions into consideration,

$$f = \frac{8B^2\cdot 10^{-7}}{\rho\gamma\beta\left(1+\frac{c^2}{a^2}\right)}. \qquad (5)$$

Let us denote by J_n the full moment of inertia of the plate including the additional constructional details. Let us also insert in (5) the values of ρ and γ for the aluminum which has the smallest value of their product. Then we shall obtain for the case of optimum damping $\beta = 0.65$:

$$f = \frac{1.58B^2\cdot 10^{-5}}{\frac{J_n}{J_K}\left(1+\frac{c^2}{a^2}\right)}. \qquad (6)$$

Expression (6) was derived for the case of $b \gg a$ and $b \gg c$. Experiments show that in practice, taking into consideration the plate end effects and other phenomena, it should be assumed that

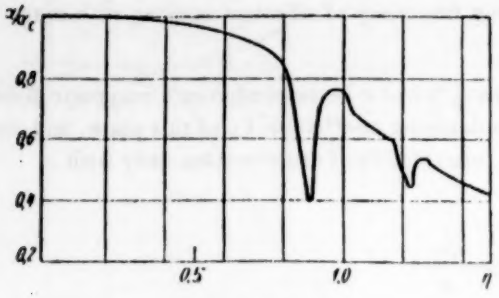

Fig. 9.

$$f = \frac{1.2\,B^2 \cdot 10^{-5}}{\frac{J_n}{J_k}\left(1+\frac{c^2}{a^2}\right)}. \qquad (7)$$

It will be seen from above equation that the highest frequency at which it is possible to use magnetic damping at a given value of J_n/J_k does not depend on the absolute dimensions of the plate, but only on the ratio of its thickness to its width. For $c = a/3$ the effect of the term c^2/a^2 becomes small. The main factor limiting the frequency is the magnetic induction. With the magnetic materials available it can be considered that in practice the maximum value of magnetic induction it is possible to obtain in a narrow effective airgap of the vibrator is equal to 20,000 gauss. Figure 6 shows a magnet of a cylindrical and Fig. 7 one of a "pancake" shape which will provide above value of induction. Magnets 1 are made of a "magnico" alloy type ANKO-4 and the pole pieces 2 of "permendure." It will be seen from Fig. 6 and 7 that the size of magnets is the maximum permissible for ordinary oscillographs. For a further increase of induction it would be necessary considerably to enlarge the size of the magnets, in order to prevent saturation of the pole pieces.

In order to obtain a vibrator with a maximum natural frequency the moment of inertia of the constructional details must be made small, of the order of 15 to 20% of the plate moment of inertia.

If we take B_{max} = 20,000 gauss, $c = 1/3\ a$ and $J_n = 1.2\ J_k$ we shall obtain from (7) that the maximum natural frequency at which magnetic damping is possible equals 3,600 cps. Although this value is considerably higher than that normally considered as the limit for magnetic damping, it may appear small compared with those of the vibrators with liquid damping. However, if it is taken into consideration that vibrators with magnetic damping are not affected by the additional mass of liquid and that it is possible to attain in them optimum damping (which is as it was pointed out, practically impossible with liquid damping), it can be considered that vibrators with a natural frequency of 3,600 cps and magnetic damping are equivalent to vibrator with a natural frequency of 10,000 cps in air and liquid damping.

Thus, with the modern magnetic materials it becomes actually possible to replace almost over the entire frequency range vibrators with liquid damping by those with magnetic damping. Vibrators with a natural frequency of 20,000 cps in air form the only exception, they are however very rarely used due to their low sensitivity and small permissible deflection angle.

It is, of course, possible to make the moving coil without a frame and provide the required damping by means of short circuited turn or by an external shunt. For greater strength of the moving coil, however, and for obtaining maximum damping it is advisable to use a solid aluminum frame. The moving coil of such a vibrator, designed for a maximum frequency, is shown Fig. 8. Where 1 is the aluminum frame, 2 the mirror, 3 the winding and 4 the torsion suspension.

Magnetic damping has one important characteristic absent in liquid damping. Liquid exerts a damping effect in any direction, whereas magnetic damping affects rotary oscillations of the coil about its axis, but hardly affects any transverse movements. Transverse oscillations can occur due to the inevitable asymmetry of the moving coil; moreover the latter begins to vibrate on its suspensions like a string at certain frequencies. This sharply decreases the amplitude of rotary oscillations due to the loss of energy in the transverse oscillations. Figure 9 shows the frequency characteristic of a vibrator with magnetic damping, troughs due to transverse oscillation are clearly seen.

Transverse oscillations can be eliminated by means of special damping (see Fig. 8). For this purpose suspensions 4 are drawn through holes in tubes 5. The tubes are filled with a small quantity of a silicon-organic liquid which, as tests have shown, remains there securely and preserves its liquid state. This arrangement damps the transverse oscillations but hardly affects the rotational oscillations.

The frame construction of the coil provides a winding of several turns of thin wire which results in a much higher current sensitivity than that of loop vibrators. The resistance of the vibrator increases, however, and its voltage sensitivity falls.

Natural frequency, cps	Frequency range for $\Delta = \pm 5\%$ cps	Current sensitivity, mm/ma · m	Vibrator resistance, ohms	External resistance, ohms (not less than)	Voltage sensitivity, mm/mv · m
3200	2200	1	3.5	0	0.3
2150	1500	6	10	25	0.2
		0.7	0.6	0	1
1300	900	16	6	20	0.6
		1.4	0.8	0	1.8
850	600	60	12	110	0.5
		2.6	1	0	2.6

It will be seen from (7) that if the end effects are neglected and the moment of inertia of the mirror is small enough, the damping will not depend on the frame length b. It can be shown that with these assumptions the current sensitivity also does not depend on the frame length. Hence, in vibrators not designed for the maximum frequencies it is advisable to make the frame shorter than in the high-frequency types. This reduces their coil resistance and increases their voltage sensitivity.

The damping of loop vibrators with liquid damping is hardly affected by the external resistance to which they are connected. The same applies to high frequency magnetically damped vibrators which have a minimum number of turns (1 to $1\frac{1}{2}$) and the largest possible frame. In vibrators designed for lower frequencies the number of turns is increased in order to raise current sensitivity; this considerably increases the effect of external resistance on damping. If the damping of the vibrator has been designed for working in a high resistance circuit and then the vibrator is connected to a shunt for measuring current, the degree of damping can increase considerably and the frequency range decrease. In such cases it is possible to connect a multiplier resistor in series with the vibrator, this will, however, drop the voltage sensitivity. It is also possible to design special vibrators with a maximum voltage sensitivity for working in low resistance circuits.

The table shows by way of an example parameters of a series of vibrators with magnetic damping. The vibrator with a natural frequency of 3200 cps has a magnetic induction in the airgap of 20,000 gauss. Vibrators for lower frequencies have a considerably lower induction.

The table gives current and voltage sensitivity for a light bean 1 m long. The "external resistance" column gives the resistance which produces a rise in the degree of damping of 8% (from 0.65 to 0.7). Voltage sensitivty is given with that resistance in circuit.

The new type vibrators have considerable advantages as compared with the existing ones: they can work in a wide range of temperatures; the damping degree temperature coefficient only amounts to 4% to 10°C; the new vibrators have a 3 to 7 times greater current sensitivity than loop vibrators; they have a stable frequency characteristic which makes frequency correction easier; contrary to loop vibrators whose overload protection is practically impossible due to the mechanical breaking of the wires, the magnetically damped vibrators can be relatively easily protected from overload by fuses; the fairly large moment of inertia of the frame makes an increase of the mirror size possible without appreciably affecting either the sensitivity or the damping. Thus the vibrators given in the table, except the one with a natural frequency of 3200 cps have a mirror of 0.8 x 1 mm instead of the usual one of 0.5 x 0.8 mm. This provides a clearer and thinner recording line.

The recent appearance of new magnetic alloys with orientated crystallization and alloys of the "supermendure" type give reasons for expecting the production of magnetically damped vibrators of a smaller size and higher frequencies.

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WIDE-BAND AUTOMATIC SUPERHIGH FREQUENCY POWER STABILIZER

V. I. Pronenko and E. N. Belikov

In superhigh frequency (SHF) measurements of power, attenuation, standing wave ratio, voltage and other radio measurements, the instability of the power level can cause considerable additional errors.

In klystrons most widely applied in radio measurements, variations in the supply voltages and in temperature lead to a simultaneous change of both the power level and frequency, a phenomenon which practically excludes the possibility of klystron generator power level parameter stabilization at a constant frequency of generation.

High stability voltage supplies and constant temperature klystron chambers lead to considerable complications of the generators and increased size, weight, etc.

Some types of klystrons (especially klystrons with a raised power output) even when fed from expensive and large high stability dc sources and placed in stabilized temperature chambers do not produce a power level stable enough for accurate radio measurements.

In connection with the above the authors of this article aimed at stabilizing the transit SHF power in order to be able to use existing generators for certain types of accurate measurements.

For stabilizing the transit SHF power it is necessary to have an automatic device which would adjust the transfer constant of the line, when the SHF power deviated from its nominal value, in order to keep the line output power constant.

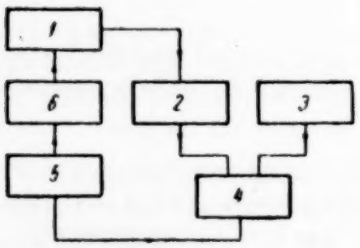


Fig. 1. Schematic circuit of an automatic power level stabilizer. 1) Controlled object (transmission line) carrying the SHF power; 2) SHF power measuring element; 3) driving element; 4) comparing device; 5) amplifier and 6 actuating device.

The schematic circuit of the SHF power level stabilizer, similar to any automatic control system, is shown in Fig. 1.

It is possible to use in the stabilizer as measuring element sensitive to SHF power, detectors, thermistors, bolometers or various types of thermocouples. For amplification purposes in these instruments it is possible to use such ac amplifiers as thermionic or transistor amplifiers or dc amplifiers of the type of thermionic, magnetic or moving coil amplifiers.

Since the sensing element supplies a dc current it appeared most convenient to use a moving coil photocompensating amplifier (photocompensator), which has a low threshold sensitivity and a small zero drift. The advisability of using such amplifiers in automatic radio-measuring instruments has been confirmed by the experience obtained on automatic thermistor bridge developed by the VNIIFTRI in which such amplifiers are used as control amplifiers in thermistor bridge current-supply stabilizers and for amplifying small direct voltages.

Electrical or electromechanical attenuators can be used as actuating devices for this stabilizer. Electrical attenuators can consist of various types of ferrite elements with electromagnets (for instance ferrite elements with longitudinal or transverse magnetic fields), whose attenuation depends on the value of their magnetic fields. Another variety of electrical attenuator consists of gas-discharge tubes, whose attenuation depends on the electron temperature of the plasma and is controlled by means of changing the dc discharge current. The defect of these attenuators consists in the effect the SHF power level has on their attenuation, which makes their application only possible for stabilizing very low SHF power levels (of the order of 1 mw or less).

An electromechanical attenuator may consist of a mechanical attenuator whose absorbing plate is displaced by means of an electric actuator.

Article [1] describes a microwave (SHF) amplitude stabilizer working at 35,000 Mc with a ferrite attenuator as an actuating device based on the principle of a rotating polarization plane of the electromagnetic field. The

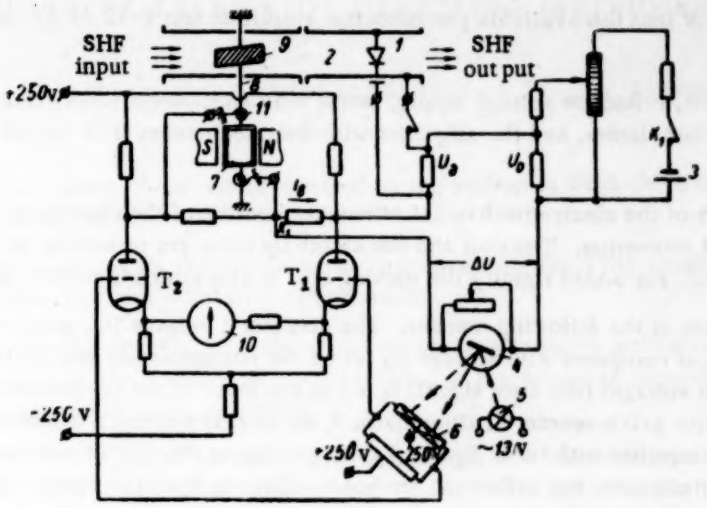


Fig. 2.

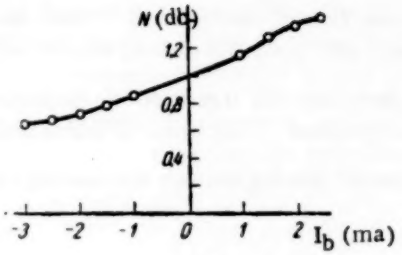


Fig. 3.

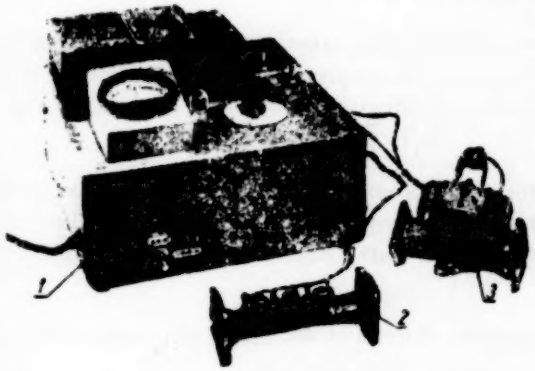


Fig. 4. General view of the stabilizer model. 1) Stabilizer unit; 2) detector section; 3) electromechanical attenuator.

specification of this stabilizer is: stabilization factor of 140, accuracy of stabilization of ± 0.01 db, limits of stabilization ± 1.5 db (limited by the amplifier) and the initial attenuation of 5 db.

The authors of the above article have also developed a stabilizing circuit for a three centimeter wavelength range with an electric attenuator in the form of a ferrite element controlled by a transverse magnetic field. This circuit employed a transit-power wide-band detector section and a photocompensator amplifier. The initial attenuation of the ferrite attenuator was set by means of a permanent magnet.

The stabilizer specification is: stabilization at the initial point of the order of 370, accuracy of stabilization of ± 0.01 db, stabilization limits of + 10 to − 3 db, and an initial attenuation of 4 db.

A serious drawback of both stabilizers is their narrow bandwidth. The existing ferrite elements cannot provide satisfactory stabilization over the entire frequency range of the waveguide employed.

In this connection the author of the present article developed a model of a wide-band stabilizer of the transit SHF power level in the three centimeter range (λ = 2.6 to 3.6 cm).

Figure 2 shows the stabilizer schematic. In this circuit a wide-band detector section serves as the sensitive element, a battery with a potential divider supplies the reference voltage, a photocompensator amplifier is used and an electromechanical attenuator is employed as an actuating element.

The wide-band untuned detector sections working in the range of λ = 2.6 to 3.2 cm and λ = 3.2 to 3.6 cm register the transit power and have an attenuation of about 10 to 13 db varying with the frequency range.

The reference voltage can be set in the range of 0 to 100 mv. The battery and potentiometer can be disconnected by means of key switch K_1 when they are not in use.

The photocompensator uses the available photoelectric amplifier unit F-12 of the semiautomatic potentiometer P-2.

The photoelectric unit, reference voltage supply, power indicator, power supply transformer, the rectifier unit with DGTs-27 germanium diodes, and the amplifier with thermionic tubes 6P1P are all mounted on one chassis.

The actuating device of the electromechanical attenuator consists of the moving coil of a type LM microammeter with strengthened suspension. The coil and the absorbing plate are suspended on caprone type "Saturn" threads of 0.3 mm diameter. For added rigidity the moving coil is also attached to hair springs 11.

The stabilizer operates in the following manner. The detector 1 voltage U_d, proportional to the transit SHF power of waveguide 2, is compared with voltage U_0 set on the potentiometer which is fed from battery 3. The difference ΔU of these voltages (the error signal) is fed to the input of the photocompensating amplifier. The latter consists of a mirror galvanometer 4, illuminator 5, an optical system, a differential photosensitive resistance 6 and balanced amplifier with tubes T_1 and T_2. According to the sign of voltage ΔU the coil of the galvanometer turns in a certain direction deflecting the beam reflected from the mirror and thus changing the illumination of both halves of the differential photosensitive resistor. This in turn changes the grid biases of the tubes and unbalances the amplifier bridge circuit. The resulting unbalance output current I_0 flows through the feedback resistor R_1 and coil 7 of the moving coil system on whose axis 8 is suspended the absorbing plate 9. The latter revolving under the effect of the torque produced by the current flowing through coil 7 alters the attenuation of the waveguide and balances out the deviation of the transit SHF power level from the set value.

The stabilizer circuit is supplied with a milliammeter 10 which shows the SHF transit power deviation from the set value. Full scale milliammeter deflections in either direction correspond to the limits of stabilization.

Figure 3 shows the relation between the attenuator loss and the current flowing through the moving coil.

The stabilizer model general view is shown in Fig. 4.

Above stabilizer model is used in the standard sets being developed by the VNIIFTRI and provides in the range of 2.6 to 3.6 cm at power levels of 10 to 100 mw and input power variations of ± 0.5 db a stable output power with variations not exceeding ± 0.01 db. The stabilization limits are ± 0.5 db.

The transfer constants of various elements of the circuit have the following values: the detector section of the transit power circuit is 16 mv/db, that of the comparator circuit is 0.1, of the photobalance amplifier is 1000 ma/mv and the electromechanical attenuator (with the 100 ohm coil shunt) is $8.7 \cdot 10^{-2}$ db/ma. The value of the stabilization factor is about 140.

In determining the speed of the stabilizer operation by means of a loop oscillograph a photograph was taken of the change in the output power with an instantaneous change in the generator output. The duration of the transient process amounted to some 0.2 sec. The speed of operation of such a stabilizer can be increased if special differentiating circuits are included in the stabilizer.

Master mechanic A.M. Tidebel' participated in the development of some of the model unit components.

SUMMARY

The development of methods and instruments for automatic transit power stabilization with a simultaneous stabilization of the frequency determining parameters, provides simple and compact generators with both a highly stable power level and frequency which is essential for many measuring instruments.

LITERATURE CITED

[1] S. I. Fray and M. F. Kimmit, A microwave amplitude stabilizer, J. Sci. Instr. v. 33, No. 9 (1-56).

MINIATURE TRANSISTOR MEASURING INSTRUMENTS

P. A. Valitov, A. I. Aleksandrov and Iu. L. Simonov

The article deals with some of the results obtained by the authors in 1956-57 in the course of developing miniature transistor measuring instruments.

The substitution of transistors for thermionic tubes considerably reduces the weight and, dimension and increases the economy in operation and reliability of instruments.

Crystal heterodyne wavemeter (Fig. 1). The development was based on technical requirements similar to those of wavemeters VG-526 and VG-527. The circuit consists of the following components: a variable oscillator, a crystal oscillator, a mixer and an audio amplifier.

The variable oscillator works with a surface-barrier transistor in a common base transformer coupled circuit. The oscillator has two variable ranges, a low frequency one from 125 to 250 kc and a high frequency one from 2 to 4 Mc changed over by means of a switch. In order to obtain a continuous measuring range from 125 kc to 20 Mc, harmonics are used.

The crystal oscillator is the basic element which determines the accuracy of the instrument. It works with a P6A transistor and the crystal is connected between the base and collector. A vacuum sealed quartz crystal of 1000 kc from wavemeter VG-526 is used in the instrument.

Apart from the fundamental frequency the crystal oscillator produces many large amplitude harmonics which are used for calibrating the variable frequency oscillator.

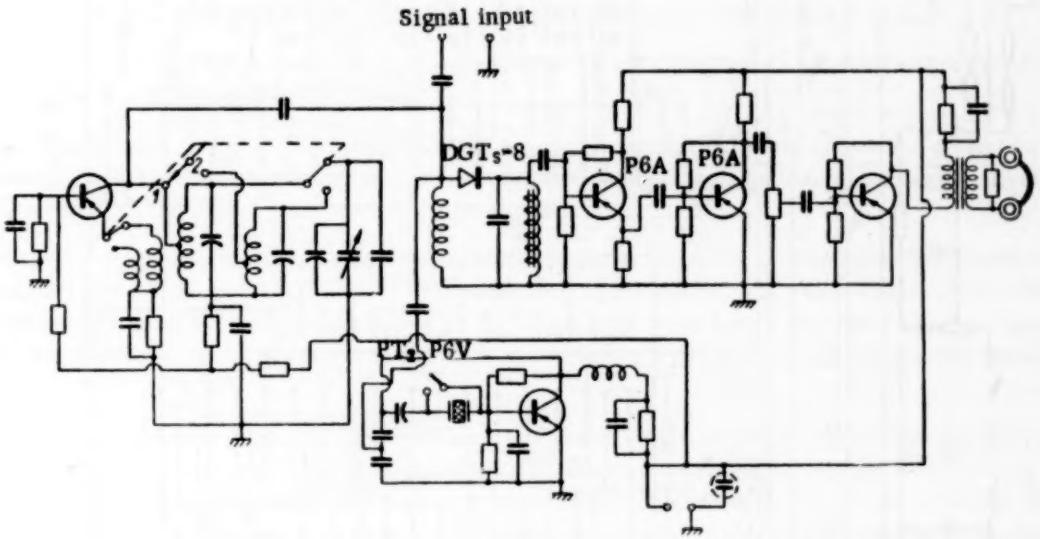


Fig. 1.

For purposes of voltage stabilization a potentiometer type biasing is used in the circuit and for frequency stabilization a negative temperature coefficient capacitor and minimum coupling to the mixer. A change of the supply voltage by ± 10% leads to a relative instability of $\pm (1\text{-}1.5) \cdot 10^{-6}$ and a change of temperature by 25 ± 5°C to a relative instability of $\pm (1.5\text{-}2) \cdot 10^{-6}$.

For the mixer stage diode DGTs-8 is used. The voltage supplied by the variable frequency oscillator varies with frequency ranges between 0.15 and 0.25 v. The voltage of the crystal oscillator fed to the mixer amounts to 10-30 mv. The voltage of the measured signal should be of the same order. Thus, the ratio between the signals which are being mixed is of the order of 10 to 15. With such a ratio there is no pulling and low current beats are well defined (there is no zero beat drift).

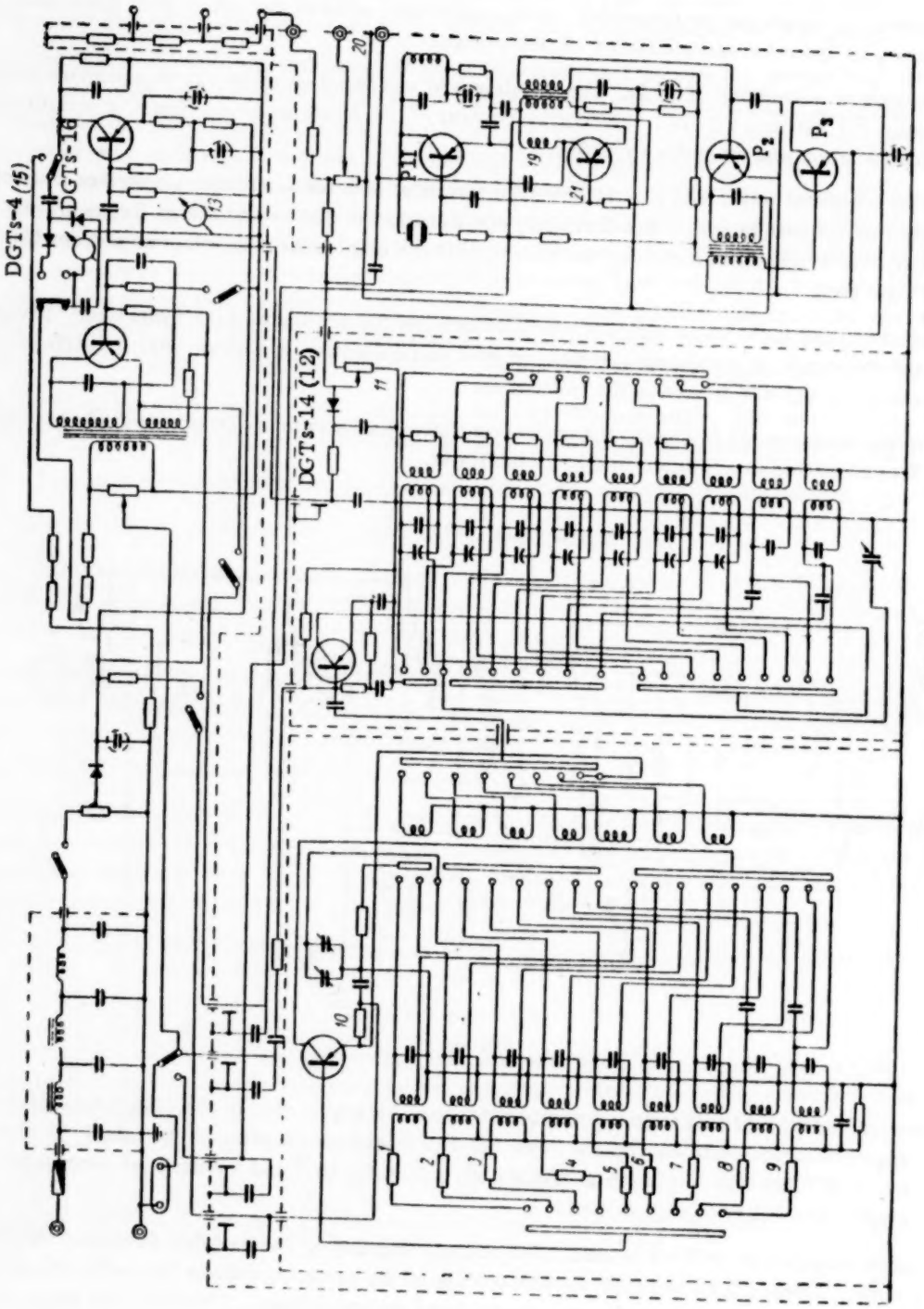


Fig. 2.

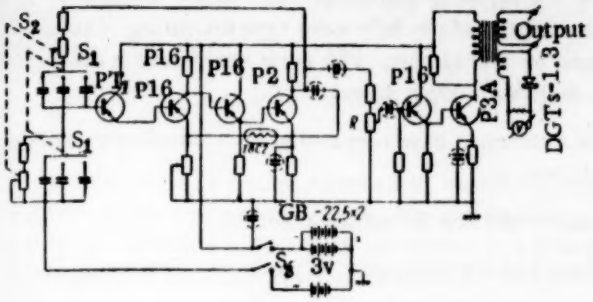


Fig. 3.

The audiofrequency channel consists of three stages. The first stage is an emitter follower and serves to match the mixer with the input of the second stage. The second stage is resistance capacity coupled and the output stage has a common emitter transistor with an output transformer.

The set is supplied from a quarter of a BAS-G-60 battery which is fixed to the set case and connected to the supply terminal block, providing a continuous working of the set for 30 hours. The total current consumption at 30 v is 10 ma.

The transistor heterodyne wavemeter is mounted on the same chassis, and fits into the same container as the VG-526 wavemeter, and uses the same basic components as the latter.

The technical characteristics of the transistor wavemeter are similar to those of wavemeter VG-526 but are superior to it in the following respects: the over-all dimensions are halved, the weight reduced to one third and the power consumption to 1/20 of the VG-526 wavemeter.

The weight and over-all dimensions can be reduced by another 30% by reducing the size of the chassis and some other details when mass production of the set develops.

Signal generator (Fig. 2) is used to calibrate radio receivers at 100 kc to 30 Mc (on the fundamental) and up to 150 Mc using harmonics. A stepped and continuously variable output attenuator provides a high frequency output at 10 μv to 10 mv with an error not exceeding 40%.

The signal generator has an internal modulator and can work in two conditions – carrier and amplitude modulated frequencies. The depth of modulation can be changed continuously from 0 to 80%.

The signal generator has an internal crystal calibrator for checking and calibrating either the signal generator itself or the receivers or transmitters under test.

The circuit of the instrument includes a carrier frequency oscillator, power amplifier, crystal calibrator, audio oscillator, a device for measuring the carrier level and depth of modulation, and potential dividers which provide adjustment of the signal generator's voltage output.

The carrier frequency oscillator works with a surface-barrier transistor in a common emitter-transformer-coupled circuit. Its full range of 100 kc to 30 Mc is divided into 9 bands. The same stabilization measures are taken in this circuit as in the variable oscillator of the heterodyne wavemeter. In order to prevent parasitic oscillation the feedback circuit has resistances 1 to 9 connected in series with it and the emitter circuit has resistor 10.

Direct amplitude modulation of the oscillator itself would lead to a large parasitic frequency modulated component. Moreover variations in the loading of the oscillator affect to a great extent its frequency stability. The internal modulation is, therefore, carried out in a special amplifier which reduces the effect of the load on the oscillator. The amplifiers uses a surface-barrier transistor working in a condition approaching class B.

The modulating voltage is fed to the base circuit.

In its properties this circuit is similar to grid modulation in thermionic tube modulators. It requires a comparatively small modulating voltage and hence, a low power audio oscillator. The high frequency voltage is fed from coupling coils to potentiometer 11 labelled "Set carrier."

The measuring device serves to set the voltage at the input of the stepped and continuously variable dividers and to measure the depth of modulation. It consists of the first detector a low frequency amplifier and the second detector.

The first detector consists of a DGTs-14 (12) diode in a series connection. The direct current component of the detector is proportional to the voltage at its input and is measured with microammeter (13).

When the output voltage of the signal generator is modulated an audio voltage will appear across the internal

impedance of the microammeter; the voltage is amplified by the capacity-resistance coupled low frequency amplifier (14) and fed to the second detector. The second detector is of the full-wave type consisting of two diodes DGTs-4 (15 and 16). Microammeter 17 serves as a load for this circuit. The same instrument is used for adjusting the supply voltage and for measuring the audio oscillator output voltage.

The audio oscillator works with a P 2a transistor (18) in a common base connection with transformer coupling. It operates at 1000 cps and provides 0 to 80% depth of modulation.

The crystal calibrator consists of a crystal oscillator, mixer and low frequency amplifier.

The oscillator has the crystal connected between the base and the collector. It produces a frequency of 1000 kc rich in harmonics.

The mixer load, choke (19), is connected to socket (20) where the amplified oscillator voltage can be used for checking and calibrating receivers.

The lead connecting socket (20) with the collector of transistor (21) runs inside the high-frequency amplifier screen. As the result of beating between the crystal oscillator frequency and that of the carrier oscillator or one of its harmonics a difference (audio) frequency will appear in the mixer load.

In order to increase the sensitivity of the crystal calibrator the beat frequency voltage is amplified by means of a two-stage low-frequency amplifier. The output low-frequency amplifier stage operates in a near to class B condition, which makes it more efficient. Small nonlinear distortion in this instance is of no importance.

The amplifier load consists of telephones connected to it through jacks. The instrument is fed from a 27 ± 3 v supply, its power consumption amounts to 1 w.

The signal generator is mounted in a case measuring 280 x 200 x 120 mm; the set weighs 6 kg. This signal generator has similar technical characteristics as the GSS-6 generator, but it has half its dimensions, 1/5 of its weight and 1/100 of its power consumption.

The RC audio oscillator with a continuously variable frequency (Fig. 3) consists of two parts, the oscillator and the amplifiers.

The oscillator consists of four transistors. The first stage is the oscillator itself. Its frequency is changed by means of resistances and capacities connected to switches S_1 and S_2.

The subsequent matching and phase-reversing stages work with junction transistors type P1B.

The fourth amplifying stage works with a P2 transistor. From its collector circuit the feedback voltage is fed to the base of the first stage.

In addition to the positive feedback, a negative feedback is also used in the oscillator in order to increase stability and reduce distortion.

In order to obtain a constant output voltage the feedback circuit contains a thermistor.

The amplifier consists of two stages. The first stage works with a junction transistor P1B and serves to separate the oscillator proper from the amplifier which is required for stable operation. The second amplifying stage works with a P3A transistor in a transformer coupled circuit.

The output voltage can be varied by means of resistor R. The output voltmeter works with a semiconductor diode DGTs-13 in a half-wave rectifier circuit. The voltmeter is calibrated in effective sinusoidal voltage values.

The oscillator range is 20 to 20,000 cps. The output power into a load of 600 ohms is 0.15 w.

The instability during one hour's operation is ± (5 to 10) cps.

The instrument is fed from batteries placed inside the instrument itself. Its power consumption is 0.36 w.

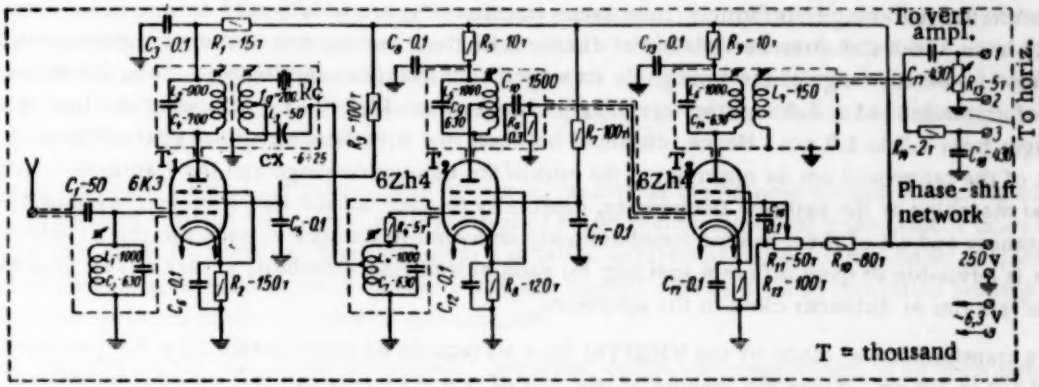
The oscillator's external dimensions are 220 x 190 x 95 mm as produced by a plant in Khar'kov.

In its basic characteristics such as frequency range, stability, accuracy of calibration, and output power this transistor audio oscillator approximates similar thermionic tube oscillators.

200 kc STANDARD FREQUENCY RECEIVER

N. A. Novinskii

The standard frequency receiver consists of a three stage high frequency amplifier with a phase shifting network at its output for producing circular scanning on an oscillograph. Since the standard (carrier) frequency of the radio station of 200 kc is modulated by a broadcasting program, a narrow band crystal filter with a differential transformer is provided in order to separate the carrier frequency from the frequency band transmitted by the radio station. The pass band of the filter depends to a great extent on the differential transformer. In practice the narrowest frequency band was obtained when the transformer had the following characteristics: $L_2 = 900\,\mu h$, ($n_2 = 250$ turns, see figure); $L_3 = 50\,\mu h$ ($n_3 = 60$ turns with the midpoint tapped). The differential transformer is wound with PEL-0.08 wire on a carbonyl iron shell type core SB-1a. Winding L_2 goes over winding L_3. Between windings L_2 and L_3 a single layer of PEL-0.2 wire is wound to serve as an electrostatic shield.



The crystal filter is tuned by means of oscillator GSS-6 and an oscillograph. First, all the tuned circuits of the receiver are adjusted to 200 kc by means of the GSS-6 oscillator, whose accuracy should be checked against the 200 kc crystal of the receiver filter. Next, a modulated signal is fed from the GSS-6 oscillator to the amplifier input (the depth of modulation should be adjusted to 100%), and an oscillograph connected to the receiver output (terminals 1 and 2). By adjusting capacitor C_f and inductor L_2 and L_3 the narrowest possible crystal filter bandwidth is obtained and, thus, the carrier frequency filtered out. The achievement of the latter is checked on an oscillograph, whose screen will show a constant carrier amplitude if the side bands are cut off by the narrow filter.

Since the frequency stability of the GSS-6 oscillator is low it should be carefully readjusted (by means of the vernier) for a maximum signal amplitude as seen on the oscillograph when tuning the crystal filter.

The bandpass of above filter is less than 40 cps.

When the standard frequency voltage is fed from the receiver output to the vertical and horizontal amplifiers of oscillograph EO-7, and adjusted to circular scanning by means of resistor R_{13} and the voltage of the oscillator under test is fed to the modulating electrode of the oscillograph cathode-ray tube (socket M) a semicircle will appear on the oscillograph screen if the two voltages are of the same frequency. If the frequencies are close to each other but not equal the semicircle will rotate at a rate proportional to the difference between them. The direction of rotation indicates the sign of the oscillator frequency error.

The relative frequency error is calculated (see instruction 215-54) from the formula

$$\frac{\Delta f}{f} = \frac{n}{ft},$$

where $\Delta f = f_s - f$ is the frequency difference between the standard and the oscillator being tested (in cps), n is the number of revolutions of the oscillograph image in time t, and t is the time of measurement in seconds (as measured on a stop

For modulating the beam of the oscillograph EO-7 cathode-ray tube a voltage of 5 to 6 v is required, therefore it is usually necessary to amplify the output of the oscillator under test to the required value.

Above receiver was used for testing the instability of transistor crystal oscillator frequencies in the range of 200 kc to 5 Mc. The receiver's sensitivity is 40 μv.

LINE-STRETCHER MATCHING TRANSFORMER

L. N. Brianskii

Line stretcher matching transformers (impedance transformers) are widely used at superhigh frequencies. They usually have 3 to 4 line stretchers placed at distances of about one quarter of the waveguide wavelength. Over the whole frequency range of the waveguide its wavelength changes considerably. Thus, for instance, in a waveguide of dimensions 11 x 5.5 mm the wavelength changes from 14.3 to 31.3 mm when the free-space wavelength changes from 1.2 to 1.8 cm. Hence, distances between line stretchers which are near optimum for the middle part of the range will not be optimum at the ends of the waveguide range and the transformer will not provide good matching at the extreme frequencies, especially so since all the line stretchers are usually placed at equal distances and all of them assume simultaneously unfavorable distance relations to the wavelength. Therefore it is advisable to have different spacings for each pair of line stretchers, so that at any frequency a part of them remains at distances close to the optimum.

Such a transformer was made by the VNIIFTRI for a waveguide of cross-section 11 x 5.5 mm working in the range of 1.2 to 1.8 cm. Since the spacing of one pair of line stretchers can become unfavorable and four line stretchers are required for good matching, six line stretchers were used in the transformer. Since the wavelength in the waveguide changes approximately by a factor 2 the minimum and maximum distances between the line stretchers also differ by a factor of 2 approximately.

The increase in distances follows the law of an arithmetic progression with the difference being equal to 3 mm (about 1/6 of the mean wavelength in the waveguide). The smallest distance between the line stretchers is 10 mm and has been chosen in this instance from the point of view of easy handing of the instrument, taking into consideration its small dimensions. In order to prevent radiation each line stretcher is taken through a bush made of an absorbing material. The transformer provides at any frequency a matching of the channel with a standing voltage wave ratio from approximately 2 to 1.03. Similar transformers can be manufactured for waveguides of other cross-sections. For waveguides of larger cross-sections the initial distance can be made equal to 1/4 of the minimum wavelength in the waveguide; all the remaining considerations remain the same. In this case at the short wavelength end of the range the line stretchers placed close to each other will mainly operate and at the long wavelength end of the range on the contrary those with the maximum spacing between them will operate.

In the transformer described above due to the arbitrary placing of the first two line stretchers these conditions do not hold strictly.

REVIEWS AND ESSAYS

A POLISH MONTHLY SCIENTIFIC AND TECHNICAL JOURNAL

"POMIARY, AUTOMATYKA, KONTROLA" (MEASUREMENTS, AUTOMATION, CONTROL) 1957

A. G. Terekhova

1957 is the third year of publication of "Pomiary, automatyka, kontrol" (PAK) the journal of the Central Technical Organization (Naczelna Organizacja Techniczna) of the Polish People's Republic. The journal is written for workers in inspection laboratories and the engineers and technicians in the instrument-making industry. The journal deals with measuring techniques, precision engineering, optics, automation and technical inspection of the quality of the measuring equipment.

One of the basic aims of the journal is to inform its readers on the home-produced measuring equipment. In a series of articles entitled "Hydraulic jet regulators of Polish manufacture and some typical cases of their application" (No. 3, 4, 8 and 11) A. Styruczli gives a detailed analysis of hydraulic regulators produced by the Polish industry and describes their use in various automatic control systems such as controlled cooling in steam installations, temperature control of blast in furnaces, etc.

In T. Stanik's article (No. 4) the principle of operation, design and construction of an electronic recording thermometer made in the Wroclaw Polytechnic Institute are described. Sensing elements in this thermometer consist either of resistances (Ni, Pt, Cu) or thermocouples (Pt Rh-Pt, Ni Cr-Ni, Fe-Const) or radiation pyrometers. The thermometer's error of measurement does not exceed 0.5% when working with alternating current and 1% on dc.

The design of a recording chronometer for measuring time intervals from $20 \cdot 10^3$ μsec to 1 sec. is of interest. Measurements are made by photographing the screen of an oscillograph. The error of measurement is of the order of 300 μsec. The recording chronometer was designed by E. Mezer and described in the article "An Electronic recording chronometer for oscillographic time measurements" (No. 6).

In an article entitled "A vanishing filament optical micropyrometer" (No. 5) J. Butkewicz describes the micropyrometer made by the laboratory of the Central Measures Administration. The micropyrometer uses a Cambridge pyrometer bulb with a cylindrical filament of 0.05 mm diameter and optical arrangement of a normal laboratory pyrometer with an extended objective focal length. The micropyrometer is designed to measure temperatures of incandescent bodies 0.2 mm in size.

The journal pays considerable attention to theoretical questions of measurement techniques, such as accuracy of measurement and calibration methods. In his article "Questions of accuracy in microhardness measurements" (No. 3) S. Katazinski analyzes errors of measurement made with Vickers' hardness pyramid due to inaccurate determination of loading and inaccurate measuring of the indentation diagonal; F. Cyborowski deals in his article (No. 3) with the effect of the heating of thermistors by the current flowing through them on the accuracy of temperature measurements; in their article entitled "Calibration of rotameters" (No. 11) E. Standy and M. Tejssejre deal in detail not only with the methods of calibrating rotameters, but also with theoretical questions connected with errors involved in rotameter measurements.

Special attention is paid to the description of standard instruments and methods of checking measuring equipment, since the shortage in reference instruments is one of the reasons impeding the development of the Polish metrological industry.

In his article "Introduction of hardness standards in Poland" (No. 5) E. Mikoszewski describes a reference Rockwell hardness tester for calibrating standard hardness steel plates which are used for checking industrial hardness testers. Instructions for the use of and testing of block gauges are dealt with in the article by T. Weisz (No. 1). In A. Zukowski's article "A method of testing electricity meter magnets" (No. 7) the principle of operation of ballistic magnetometers are described.

The journal devotes considerable space to foreign metrological developments. Many articles deal with the description of instruments of a new design: thus J. Kurylowicz's article (No. 1) on the principle of operation and application of a permalloy probe for measuring weak magnetic fields in the range of 10 μoersteds to 10 oersteds, an abridged translation of A. Nagatkin's article "New Soviet manometers with a tubular spring for very high pressures" (No. 9), a translation of Fribel's article "Liquid metering barrels" (No. 11 and 12) describing the principle of operation, construction and technical details of application of metering barrels.

Reviews of measuring equipment shown at international exhibitions are regularly featured, including that of the measuring equipment Stockholm exhibition (No. 2), the 26th Poznan (No. 6, 9 and 10) fair and London exhibition of instruments, electronics and automation (No. 12).

Considerable attention is paid to Soviet instrument-making developments. Thus, in Z. Gaiewski's article "Measuring instruments at the All-Union Industrial Exhibition" (No. 10) a review of the Soviet measurement technique developments in 1957 is given on the basis of the exhibits shown. In such long descriptive articles as for instance "DC potentiometers and their applications" by F. Tiborowski (No. 10) and "Thermoelectric regulators with pointers used in electric heating installations" by L. Michaski (No. 11) and others, considerable space is taken up by descriptions of Soviet made instruments.

The automation section of the journal is mostly descriptive. This is probably due to the as yet low level of industrial automation in Poland. In order to improve the state of this important technical development, an interdepartmental conference on industrial automation was held in July 1956, and an industrial automation program for the current five-year plan worked out at the conference. The journal acquaints its readers with the basic concepts of the automation theory, the paths of its development and the state of industrial automation in the most technically advanced countries, thus assisting the speedy implementation of the proposed program.

These aims are pursued in a series of articles by W. Alpert entitled "Basic problems of control theory" (No. 6, 7, 10 and 12) in which the author reviews the basic principles of automatic control and proposes an appropriate terminology. In an article entitled "Principles of operation of electronic analogue computers" (No. 2 and 3) A. Sowinski analyzes in detail the schematic circuits of computers for adding, multiplying, differentiating and integrating for analyzing algebraic and differential equations and for investigating automatic control closed loop systems.

In K. Kassenberg and M. Badalski's article "Operation of a position regulator" (No. 6) an equation for a temperature control system of an electric oven is derived and the method of calculating the integrating link of a system with a thermal feedback is examined.

Side-by-side with the material which in the main has an instructive value there are articles which describe the state of automation of some of the Polish plants. Thus, in No. 5 of the journal, B. Chorowski, T. Stanik, S. Kolkewicz and B. Szot describe in detail in their article "Automation of open-hearth furnaces" the system of automatic control in the open-hearth furnaces of the metallurgical plant "Mir."

The journal deals fully with optical measuring instruments. In each of the 12 issues there is at least one article on the subject of optics.

In the article "Application of interference for investigating surface topography" (No. 1) K. Fulinski investigates the theory of double beam and multibeam interference in prisms and gives a mathematical determination of conditions for interference. In addition the article deals with the principles of operation of an interference microscope, conditions of maximum accuracy for measuring surface irregularities and the interference method of investigating surface topography by means of a conventional microscope supplied with an opaque illuminator.

In M. Gaj's article "Construction of negative eyepieces" (No. 2) a design of a negative microscope eyepiece for compensating the curvature of the objective's field of vision is given. In No. 6 and 8 of the journal in an article entitled "Mirror photographic objectives" the same author describes various designs of photographic

objectives and gives a method of their calculation when used with compensators. M. Pljuta's article "Microscopy with phase contrast devices for transient light" (No. 10 and 12) contains a description of a design of a phase contrast device and the construction of a microscope incorporating this device.

A series of articles in the nature of a discussion deal with the principles of designing measuring instruments, methods of design work, and the analysis of measuring errors. R. Calikowski's article "An example of applying design methods for working out technical specifications for a new laboratory instrument" (No. 4 and 5) starts the discussion suggesting a typical designer's approach when dealing with a new instrument, noting the aims of the design and means of achieving them at each stage of the development work.

Considerable space in the journal is devoted to articles dealing with modern methods of measuring instrument components manufacture, methods of improving production inspection and economic questions involved in changing over to new techniques.

In the article "Production scrap charts in engineering" (No. 1, 3 and 4) A. Wisznewski raises the question of the efficiency of production scrap charts for analyzing causes of scrap and methods for its elimination; the author suggests a unified form of charts developed by him. J. Bata's article "Accuracy of journal bearings and methods of attaining it" (No. 5) deals with production methods providing the required accuracy and outlines the direction in which to develop the inspection methods. Several articles deal with the manufacturing methods of corundum used in watches (No. 2) and that of parts pressed out of ceramic materials (No. 8).

In the article "Production of rectangular colorimetric vessels and measurement of their effective length" (No. 2) S. Kraszewski and S. Senkowski describe in detail the production and technical inspection methods of colorimetric vessels with rectangular walls for photoelectric and optical colorimeters produced by the Warsaw laboratory equipment and measuring instruments plant.

The problem of economic utilization of the complement of machine tools in instrument-making plants is dealt with by K. Wisznewski in an article entitled "A method of determining the number of workers required for operating a complement of machine tools" (No. 9).

In the same section of the journal questions of technical inspection of production are also dealt with. Z. Powlawski's article "Review of the basic applications of ultrasonic fault location in the metallurgical industry" (No. 8 and 9) deals with the application of the latest methods of fault location citing the experience obtained in one of the Polish plants for inspecting turbo-generator components.

In a number of articles the statistical method of controlling the quality of production is advocated. Thus, J. Obalski's article "Experience of introducing statistical quality control" (No. 5) describes the application of the statistical method of production quality control in Poland and abroad, and R. Zelinski's article "Statistical method of checking the life of lamps" (No. 10) deals with the economy and simplicity of the statistical method. The efficiency of the statistical method is also stressed in J. Sedlacek's article (translated from Czech) "Modern methods of evaluating life time" (No. 11).

Considerable attention is paid to the general problems of metrology. In the article "Measurement technique as a science" (No. 7) the director of the Technological Institute of the Hungarian Acad. Sci. G. Sztriker shows that measurement technique deserves to be considered as a separate science, demonstrates the relation of metrology to physics and technology and determines the terms of metrology, measurement technique and instrument technique.

Materials of the International Weights and Measures Committee, the International Organization of Legislative Metrology, the ISO and of other international organizations whose activity is related to measurement techniques appear regularly in the journal.

A few articles deal with the question of standardizing measuring instruments. Thus,No. 3 carries an article by Z. Gaewski on the standardization of thermocouples, No. 4 the polemic article of J. Obalski on the standardization of the basic metrological definitions and No. 7 carries an article by E. Time on the standardization of manometric flowmeter, etc.

A number of articles deal with problems of improving the production inspection organization, the necessity of training metrological personnel and a more efficient operation of test laboratories. The necessity of exchanging experiences with the State agency for measures and measuring instruments of the USSR is stressed.

In addition to the already described sections of the journal there exist other sections containing auxiliary and informative material: bibliography, short technical notes and reviews, list of the most interesting articles in foreign journals of a similar nature, etc.

The journal deals systematically with the latest development work of laboratories and scientific research establishments in instrument design and methods of their application.

MATERIAL RECEIVED BY THE EDITORIAL BOARD

EFFICIENT UTILIZATION OF MEASURING INSTRUMENTS

P. N. Stebelov

Regulations 12-54 of the Committee for Standards, Measures and Measuring Instruments of the USSR Council of Ministers and administrative instructions on maintenance provide for a correct and serviceable maintenance of measures and measuring instruments, and their efficient use. However, the design and installation organizations and owners of instruments often break these rules. At the Voroshilov metal plant, for instance, the measuring and control instrument boards of the No. 1 sheet-metal shop ovens are placed 3 m from the slab output windows, which makes the temperature inside the instruments reach + 70°C. In addition the instruments are subjected there to strong vibrations and shocks. Hence, the instruments are often put out of action and the required accuracy of measurement is not attained. Instruments in the control positions of the annealing shop regenerative heating pits are in a similar condition.

In the same factory, owing to the nonobservance of regulations 27-54 in designing and installation of flowmeter diaphragms, the majority of flowmeters have been replaced by dial instruments.

In the Gudronov processing plant of the "Donetskugol" trust, the Maksimov processing plant of the "Ugleobogashchenie" Lugansk trust, the Severskaya pit of the "Krasnodonugol" trust, etc the truck weighbridges are placed immediately under the hoppers; as the result of this the mechanism of the weighbridges is flooded with water and smothered in coal dust which leads to their rapid deterioration and makes their repairs difficult. Inthe Krivoi Rogprocessing plant of the "Ugleobogashchenie" Lugansk trust the control and instrument board is mounted in an unsuitable place, the pyrometer millivoltmeters are used without correction for the temperature of the thermocouple; loose ends and compensating leads are missing.

The designing and, installing organizations and owners of instruments should pay attention to the correct choice, placing and use of measuring instruments.

IMPROVING THE QUALITY OF MEASURING INSTRUMENTS

I. S. Vasilenko

The universal microscope UIM-21 of the Leningrad plant and the large projector BP of the Novosibirsk plant are well designed and finished, and easy to use. Mass production of these instruments bears witness to the mature skill of the personnel of these plants.

At the same time the above instruments have a number of defects. In the BP projector such defects consist of:

1. Low quality adjustment of objectives, leading to errors in magnification; one of the reasons for this, is the inadmissible slackness of the thread of fixing collars which buckle when tightened by a grub screw; in our objective with a magnification of 20 the fixing collar had a diameter outside the permissible limits;

2. a blurred filament image after centering the illuminating bulb;

3. impossibility of obtaining a clear image in reflected light with stop adjustment;

4. too short a mains lead;

5. careless assembly of the table lifting screw, backlash, dents, pronounced filing scratches on the polished surface;

6. sharp edges (swallow tails) on the table runner, making it impossible to assemble the table without filing the edges.

Other defects were also found in BP projector: the swivel (with the mirror) could only be turned with great difficulty, since the finish of the rubbing surfaces was too rough; chromium plating of the object sliding table grooves was ribbed. The table runner set screw was flattened out with a hammer blow and forced into its seating.

The factory was advised that the extraction of the object glass should be made easier, the lines on the screen should be crossed at the center to facilitate measurements and finally that the 10 mm lighting conductors should be changed for lighter and more flexible leads.

The systematic defects of the UIM-21 microscope consist of:

1. careless adjustment of the OGU-21 mismatch of the divisions of the two angle scales in the same plane, lack of agreement between the direction of calibration lines and that of the table travel;

2. blurred filament image;

3. uneven, "trembling" contour lines (double figures) on scales ST-3 and IB-21 which spoil the appearance of the scales;

4. careless fixing of the writing table board: its small fixing wood screws were poked into holes, when the instrument was first assembled the board came off.

The nonsystematic but nevertheless serious defects include the following:

1. scale ST-3 was dusty and covered with large dark spots impossible to remove; the minutes scale did not tally with the degree scale;

2. the tightening of chuck IB-21 moved the spindle through 40 to 60 seconds of the arc.

The Leningrad factory was advised to place the lighting leads inside the body of the instrument, or if they are left outside shorten them by mounting a distribution box at the back of the stand. The leads themselves should be made lighter and more flexible which will save money and improve the appearance of the instrument. The wood screws fixing the writing table board should be replaced by countersunk screws (with nuts).

The factory should supply the instrument with a special dust cap with an opening for protecting the condenser lens from shocks.

Good and, on the whole, satisfactory instruments such as the UIM-21 microscope and the BP projectors should be impeccable in every respect.

STANDARDIZATION OF CONSTRICTING DEVICES FOR MEASURING FLOW

A. N. Avdashev

In design work the nearest size pipes to the calculated value are chosen from catalogues. However, building organizations receive pipes in large consignments of commercial sizes and often do not receive the special pipes specified in the design.

The pipes are manufactured with certain tolerances which makes it difficult to select from the consignments the required connecting pieces for the designed constriction devices.

Instrument-making plants manufacture flow-measuring outfits according to the customers' requirements, from the information obtained from questionnaires filled by the designing organization, without taking into account the potentialities of building organizations. In many cases the diaphragms received do not fit the commercial-size pipes.

In this connection the assembly is made either in contravention of the regulations 27-54 and assembly specifications, which results in an inaccurate measurement of liquids or gases from the very start, or the constricting devices are recalculated and made again, which obviously leads to excessive expenditure.

In order to avoid the difficulties in installing constricting devices it is necessary

1) to manufacture calibrated pipes with a mean internal diameter in whole units for each type of pipe;

2) to work out unified standards for constricting devices in outfits including flanges and connecting devices, entrusting their manufacture to specalized organizations and relieving the instrument making plants from the production of constricting devices; to send the outfits to special installation organizations of the inspection and automation departments of the economic districts; to organize the assembly of the restricting devices and the boring of measuring washers in the shops of the special installation organizations of the inspection and automation departments;

3) to make the instrument-making plants produce instruments with 100% uneven scales, if necessary, to order, with a double scale calibrated in percentage and measuring units, which will facilitate instrument assembling in industrial installations.

If above measures are taken the installation of constricting devices will be carried out according to regulations 27-54.

Editorial Note. The author raises correctly and in good time the important question of standardizing (on an All-Union scale) and providing the required accuracy of measurement of liquid and gas flows, as well as facilitating the installation of measuring devices.

Such measures can be worked out and introduced by the State Scientific and Technical Committee of the USSR Council of Minsters.

IN THE COMMITTEE OF STANDARDS, MEASURES AND MEASURING INSTRUMENTS

I. NEW SPECIFICATIONS FOR MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE

(Registered in May-June, 1958)

New Instructions for Checking Measures and Measuring Instruments.

Instruction 7-58 for checking draft gauges, micromanometers and differential manometers. Replacing instruction 7-54 of the Central Bureau of Measures and Measuring Instruments of the USSR.

Instruction 222-58 for checking tube voltmeters at frequencies up to 300 Mc.

Operating instructions for checking measures and measuring instruments approved by the Technical Administration of the Committee.

Operating instruction No. 169 for checking (calibration) of standard hardness gauges of the 2nd category.

Operating instruction No. 170 for checking photoelectric color pyrometers.

Operating instruction No. 171 for checking micromanometers types MM, ALD and Prandtl.

Operating instruction No. 172 for checking optical vanishing filament pyrometers in the range of 1800 to 6000°C.

II. MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE, AS THE RESULT OF STATE TESTS, FOR USE IN THE USSR

Universal micrometers, trade mark K-6, made by the Moscow City Sovnarkhoz State register No. 1178-58.

Ground resistance, spark-quenched measuring sets, trade mark M1103 made by the Kiev Sovnarkhoz. State register No. 1179-58.

Heterodyne wavemeter, trade mark VG-526U, made by the L'vov Sovnarkhoz State register No. 1180-58.

Tube voltmeters trade mark VLU-2, made by the Leningrad Sovnarkhoz State register No. 1181-58.

Micromanometers trade mark MM-250, made by the Khar'kov Sovnarkhoz State register No. 1182-58.

Industrial traction dynamometers, trade mark DT-02, made by the Moscow City Sovnarkhoz State register No. 1183-58.

Glass lactohydrometers (without a thermometer), made by the "Laborpribor" plant of the Moscow Regional Sovnarkhoz State register No. 1184-58.

Thermochemical automatic gas analyzers, trade mark TKhG-5, made by the State Committee for Chemistry of the USSR Council of Ministers State register No. 1185-58.

Coating thickness gauge, trade mark EMKP-4, made by the State Committee for Defense Technology of the USSR Council of Ministers State register No. 1186-58.

Coating thickness gauge, trade mark IT-2, made by the State Committee for Defense Technology of the USSR Council of Ministers State Register No. 1187-58.

CHANGES IN VALID INSTRUCTIONS FOR CHECKING MEASURES AND MEASURING INSTRUMENTS

J. M. Staroverov

Instruction 87-55 for checking survey tape measures and instruction 89-58 for checking metal tape measures are amended to agree with the new GOST 7502-55 on "Metal tape measures."

Instruction 87-55 column 3 of Table 2 section III reading: "Maximum permissible deviation of discrete metric divisions" is deleted and the note to Table 2 changed to :

"The deviation from its nominal value of the actual distance from any division to either end of the tape measure must not exceed the quantity

$$\delta = \pm \frac{a}{l} n \text{ mm}$$

where a is the permissible deviation for the total length of the tape measure, l the nominal length of the tape measure, m, n the number of meters from the end in question to the division being checked (parts of a meter are taken as a whole meter).

For n = 5 m and less the permissible deviation (δ) is taken as ± 0.3 mm.

Above modifications take into account the determination of the tape measure length deviations from either end and the regulations for deviations in its length according to the section of the scale under consideration.

In instruction 89-55, the scale markings width is defined more precisely and for this purpose paragraph 5a is made to read:

"The width of the markings must be within the limits of 0.25 ± 0.05 mm. The markings must be of the same width throughout their length."

The manufacture of precision tape measures is taken into account by adding a second note to Table 2 in the form of paragraph 6a which reads:

"Precision tape measures should be made on request with smaller permissible deviations of the length of the scale and of its divisions according to an agreement reached with the customer and with a marking width of 0.2 ± 0.05 mm. Such tape measures should carry a serial number and be accompanied by a test certificate".

Instruction 60-54 for checking counter scales is amended with respect to their zero unbalance as follows:

"The permissible deviations of the unloaded scales balance should be:

1 g for scales with a total capacity of 5 kg, 10 g for scales with a total capacity of 50 kg, and 50 g for scales with a total capacity of 500 kg."

In instruction 49-57 for checking unequal-arm portable scales the requirement of a 20 minute overload in checking new scales is deleted.

Moreover the technical requirements for these scales have been more clearly defined and the following amendments made to the requirement contained in the appendix to instruction 49-57.

Item 4 of the technical requirements now reads:

"The components of scale balances should be made of the same materials as those specified by GOST 7863-56 for weights balances with the exception of the cast-iron platform levers for balances of a 200 kg or smaller capacity which should be made of cast iron of a quality not inferior to grade SCh 15-32 according to GOST 1412-54, and the calibrated balance beam or the attached rail with notches for the sliding weight, which should be made of steel of a grade not lower than St. 6 according to GOST 380-50 or from steel of grade St. 3 which is made as hard as that of grade St. 6 either by carbonization or admixture of chromium."

The last paragraph of item 6 of the technical instruction now reads:

"The finish of the groove and the tooth of the sliding weight should not be lower than grade 7 according to GOST 2789-51. The hardness of the sliding weight tooth should be within the limits of 44-47 units by the S – OST 10242-40 scale"

Item 8 of the technical requirements of Table 2 is supplemented by:

"Markings of the additional scales of balances below a 200 kg capacity drawn on scales less than 16 mm in width can be shortened but not to less than half their length."

Above changes together with those published in the journal "Measurement Techniques" No. 2, 1958 regarding weight measuring instruments, include all the changes to the valid regulations for checking measures and measuring instruments adopted in 1958 before and including July 1, 1958.

Changes to instruments adopted in 1957 are published in the "Index of instructions, operational instructions and regulations for checking measures and measuring instruments" dated January 1, 1958. ("Standartizdat" Press).

Orders for the index should be addressed to the circulation department of the Standartizdat (Moscow, I-90, 2nd Meshchanskaia St. No. 51).

CORRECTION

Owing to an error made by the VNIIM in the article entitled "Metrological work in the sphere of ionizing radiations" printed in the journal "Measurement Techniques" No. 6, 1957, the name of one of the authors was omitted, which was F. M. Karavaev.

ALL-UNION COMPETITION FOR DESIGNING INSTRUMENTS FOR THE TECHNICAL RATING OF PRODUCTION

The Scientific-Technical Society of the engineering industry in conjunction with the Labor Scientific Research Institute of the State Committee for Labor and Wages Problems of the Council of Ministers of the USSR have announced an All-Union competition for the design of instruments for technical rating of production.

The object of the competition is the development of the most rational types of instruments which could be adopted for introducing technical rating in industrial plants and production-research organizations.

The following types of instruments will be accepted for the competition: instruments for time and motion study by means of observations (stop watch or photographic), for investigating labor processes with the view of their rationalization, for determining rational operating conditions for the equipment and instruments, for classifying work, determining loading coefficients and useful technological equipment coefficients.

Instruments entered for the competition can be designed either for use in various industries or in one industry only with the view of using it in any type of production within the industry.

The design of the instruments is not specified; they should, however, provide automatic recording of the observed processes, free the observer from numerous calculations in connection with determining and fixing production rates, and at the same time ensure the required accuracy and satisfy the aims and objects of the investigations.

The competition will be open until October 15, 1958. The competition results will be announced 2 months after the closing date. For the best accepted designs prizes of 2,500 to 10,000 roubles will be awarded.

Basic organizations, sections, committees, work crews and individual members of engineering Scientific Research Organizations as well as scientific research institutes, production-research organizations and individual scientists and technicians are eligible for the competition.

Detailed conditions of the competition have been dispatched to all the scientific and technical organizations in the engineering industry, to Councils of National Economy, industrial and scientific research institutes and establishments of higher learning.

Any correspondence in connection with the competition should be addressed to the Scientific-Technical Organization of the Engineering Industry (Moscow, B. Cherkasskii Lane, No. 7) or to the Labor Scientific Research Institute (Moscow, B-64, Chkalov SF. No. 34) with the inscription "Instruments Competition."

Telephone inquiries: B 8-63-34 (NTO Mashprom)
B 7-00-22 ext. 9 (NII labor).